Staff Technical Workshop

Analytical Tools Used to Develop the Amendment to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary and Supporting Revised Substitute Environmental Document (SED)

December 5, 2016

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REGIONAL WATER QUALITY CONTROL BOARDS

Workshop Purpose

- State Water Board staff technical workshops on December 5 and December 12
- To describe the models and tools used in the Substitute Environmental Document (SED) for the amendment to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan)
- Answer questions to help interested persons prepare oral and written comments

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Outline (Dec. 5)

- Welcome, Introduction, and Overview
- Facilitation
- Water Supply Effects Model Methods
- Water Supply Effects Model Results
- HEC5Q Temperature Model and Results
- Ecological Benefits of Flow Alternatives
- Closing Session / Next Steps

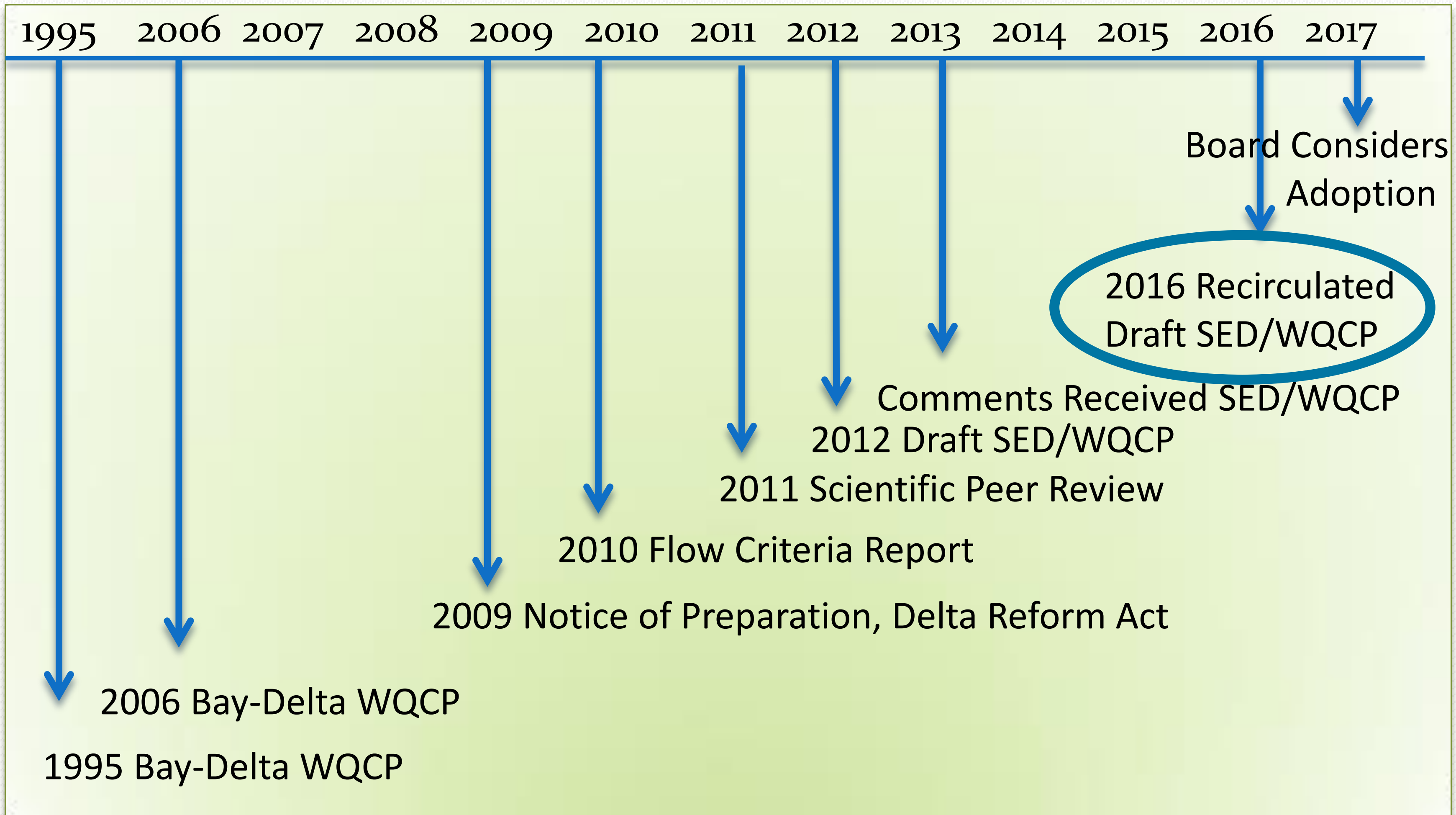
The Project

Update of Bay-Delta Plan:

- San Joaquin River flows for reasonable protection of fish and wildlife
- Southern Delta salinity for reasonable protection of agriculture
- Program of implementation

5

WQCP/SED Timeline



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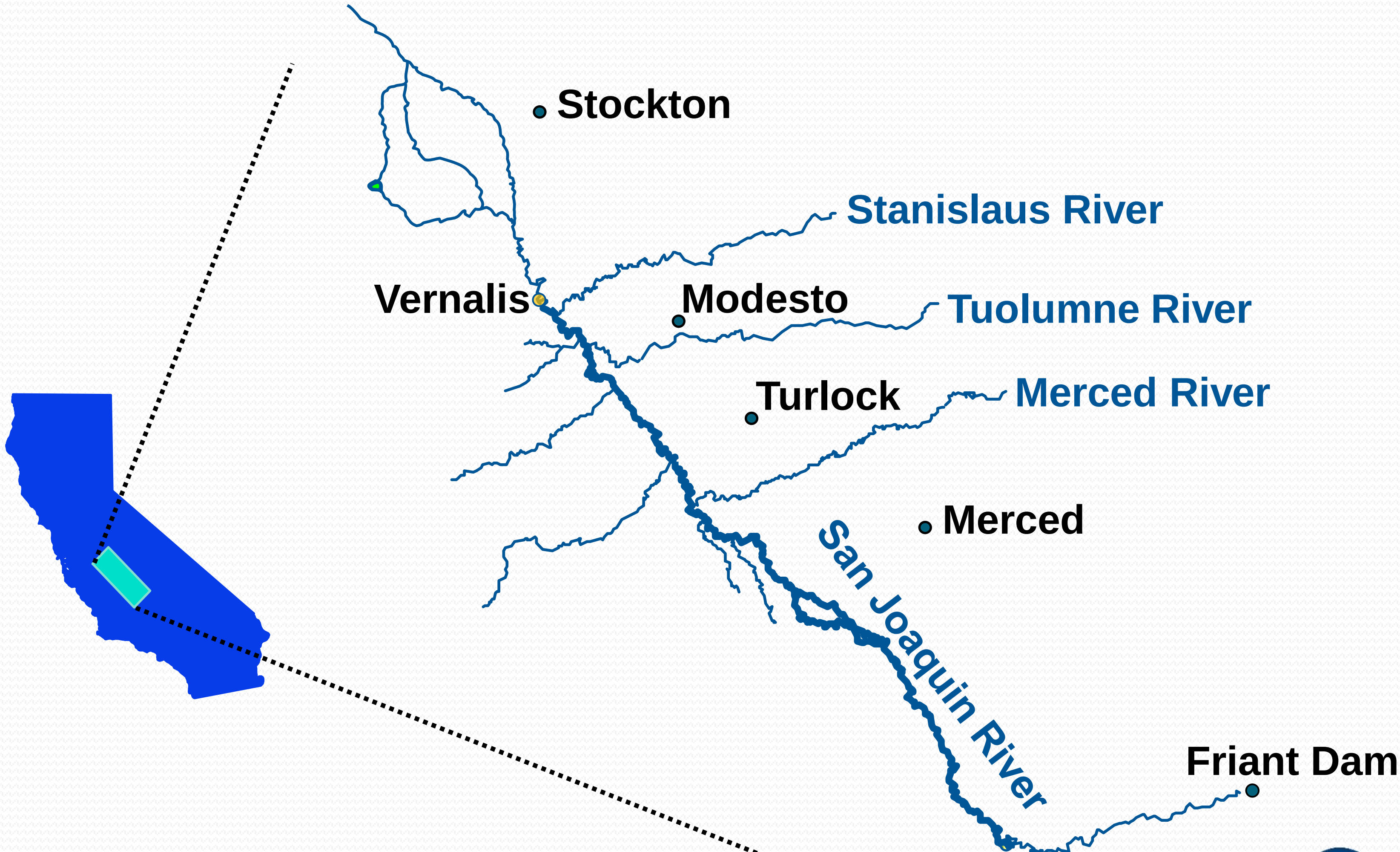
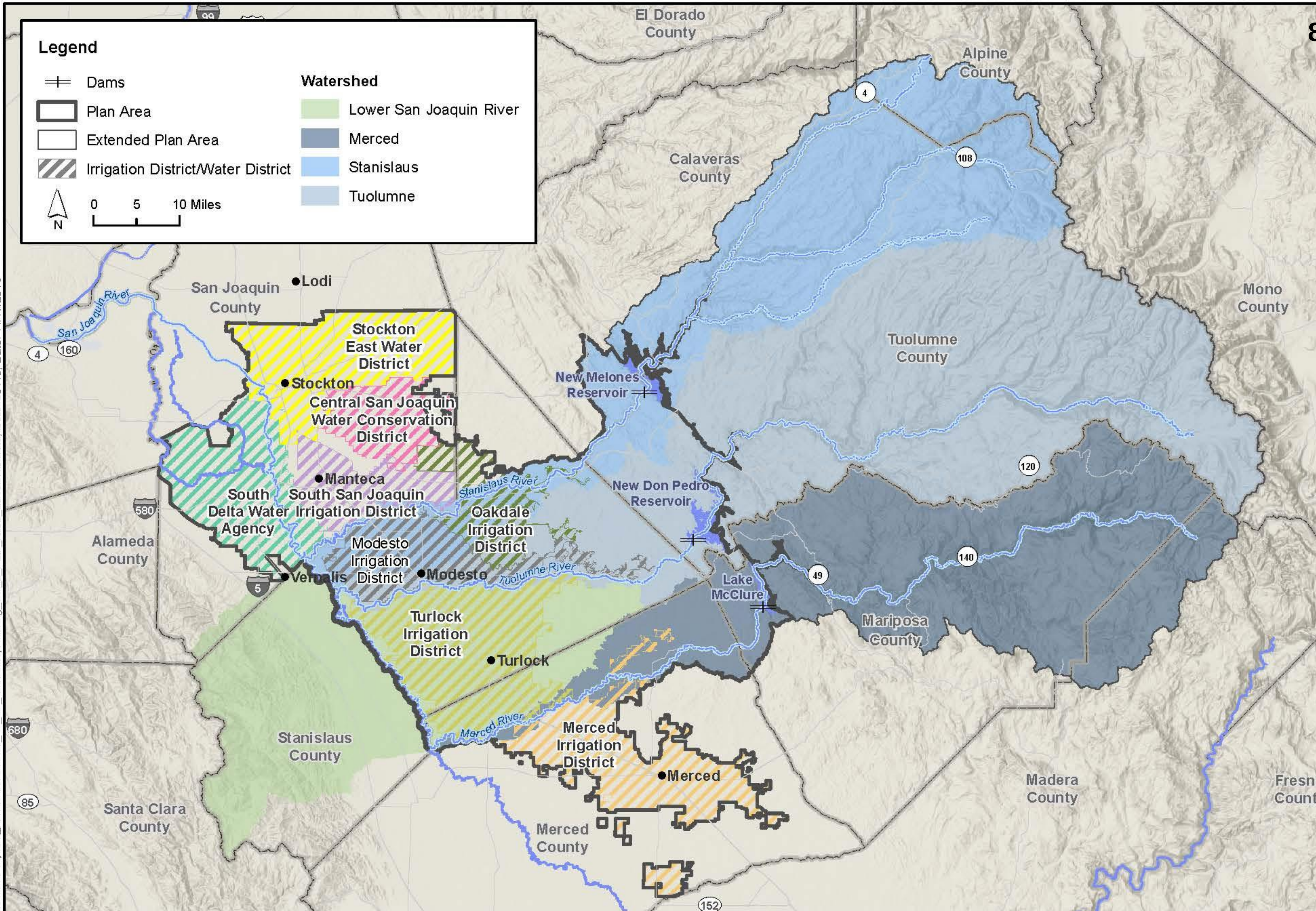
Current Plan Out of Date

- Plan last updated 21 years ago in 1995
- Species have been declining – the need for update was identified 10 years ago (in 2006 Plan update)
- Endangered Species Act increasing water restrictions
- Administration's California Water Action Plan directs the State Water Board to complete the update of the Plan to further achievement of the co-equal goals in the Delta
  1. Providing a more reliable water supply for California
  2. Protecting, restoring, and enhancing the Delta ecosystem

Lower San Joaquin River (LSJR) Basin





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Purpose and Goal

- To establish flow objectives for the February–June period and a program of implementation for the reasonable protection of fish and wildlife beneficial uses in the LSJR Watershed, including the three eastside, salmon-bearing tributaries (the Stanislaus, Tuolumne, and Merced Rivers)
- To establish salinity objectives for the reasonable protection of southern Delta agricultural beneficial uses and a program of implementation to achieve the objectives

Why Focus on Flow?

- Scientific studies show that flow is a major factor in the survival of fish such as salmon
- Many benefits of flow, including improved growth and survival of native fish by improving water temperatures and increasing floodplain habitat
- Flow affects risk of disease, risk of predation, reproductive success, growth, smoltification, migration, feeding behavior, and other ecological factors
- Non-flow measures can also be important, but State Water Board has limited authority to require non-flow measures

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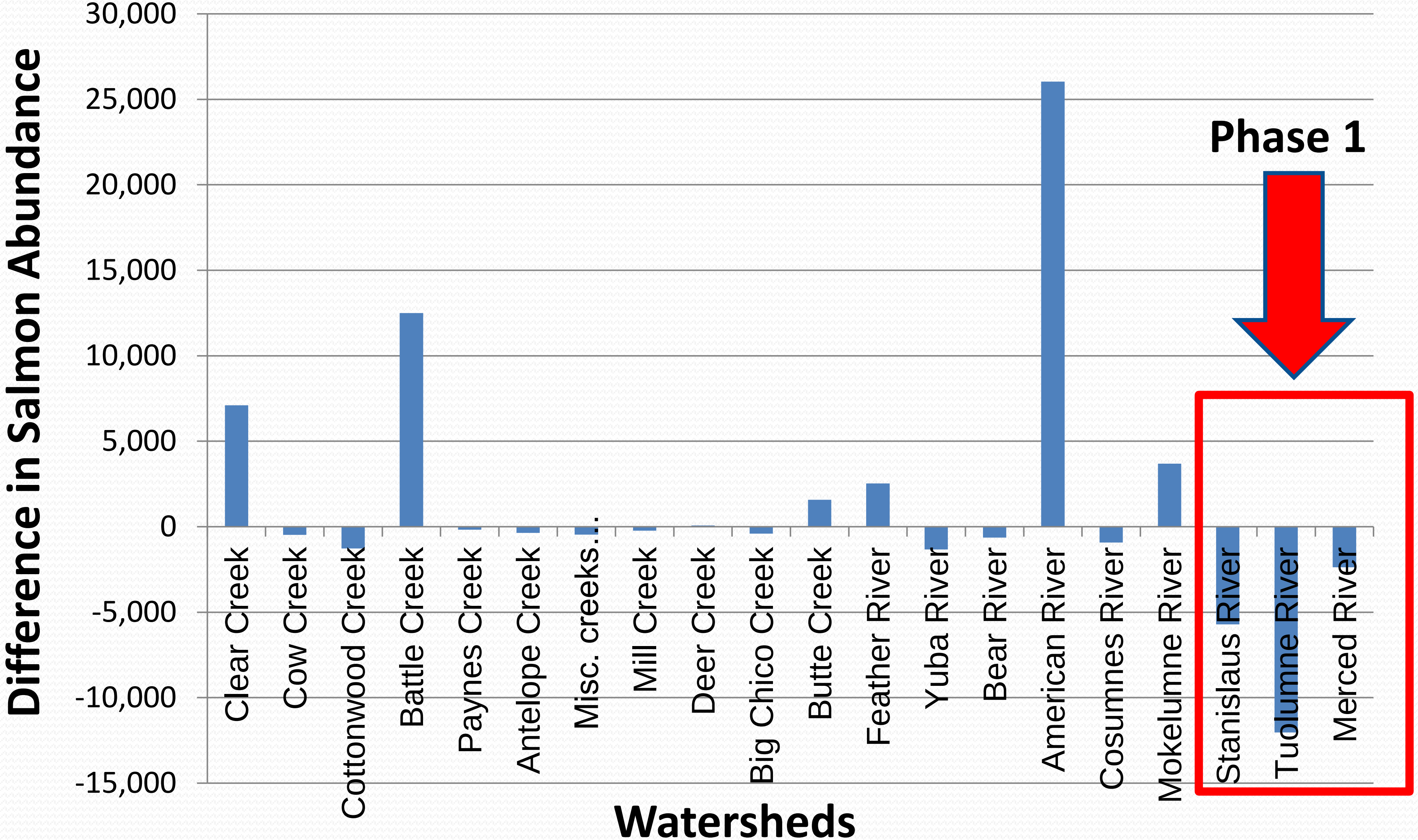
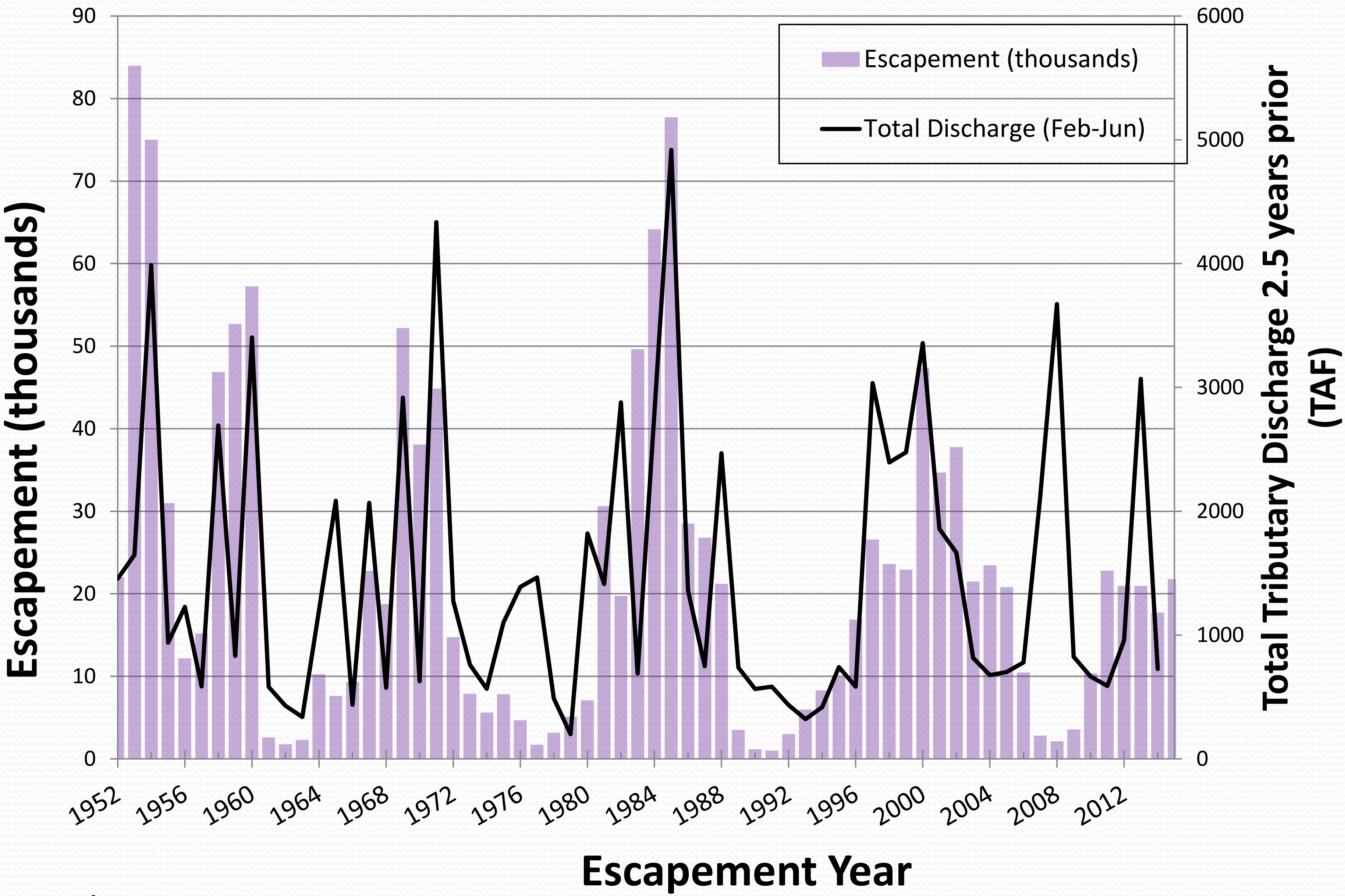
Difference in Adult Fall-run Chinook Salmon Natural Production (1992 to 2011 average minus 1967 to 1991 average)



SED Figure 19-1

Corrected Tuolumne River

Adult Salmon Returns and Flows Experienced by Juveniles



SED Figure 19-2

This is Hard, Requires Balancing

- State Water Board's 2010 flow criteria report – a purely technical assessment and no balancing – concluded that 60 percent of flow should be left in the LSJR for the benefit of fish
- Current uses (agriculture, drinking water) rely on up to 80 percent or more of the unimpaired flow
- Unlike the 2010 report, this staff proposal considers other uses and aims to strike a balance among competing uses of water
- The staff proposal recommends a range of between 30 and 50 percent of unimpaired flow, with a starting point of 40 percent – this is a big increase

This is Hard, Requires Balancing

- This is less than what environmental and commercial fishing interests favor, and more than agricultural and affected urban users want
- Balancing is hard, but is what we are called upon to do
- Because it is hard, State Water Board has a long history of encouraging settlements

Settlements are Encouraged

- The flow proposal includes "adaptive implementation," which allows adjustments so water is used wisely and more effectively – implementation of non-flow measures could also reduce the flows needed
- Board is looking for durable local solutions that will improve flows and other conditions that can reduce the need for flow
- Local water agencies and local people working with agency experts and other organizations can provide the foundation for such durable solutions
- The California Natural Resources Agency is leading settlement discussions to explore the potential for a comprehensive agreement on environmental flows in both the San Joaquin and Sacramento River basins

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Current SJR Spring Flow Objective

- One compliance location: Lower San Joaquin River at Vernalis (inflow to Delta)
- Minimum monthly average flow rates
- Includes "pulse" flow during a 31-day period in April and May of each year
- USBR only responsible water right holder

Proposed LSJR Flow Objective

- Applies to salmon-bearing tributaries-- the Stanislaus, Tuolumne, and Merced Rivers
- Narrative Objective:
  - Maintain inflow conditions from the SJR watershed to the Delta at Vernalis sufficient to support and maintain the natural production of viable native SJR fish populations migrating through the Delta
- Numeric Objective:
  - Feb - June: 30% - 50% unimpaired flow
  - Starting point of 40%
  - Unimpaired flow: the natural water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds

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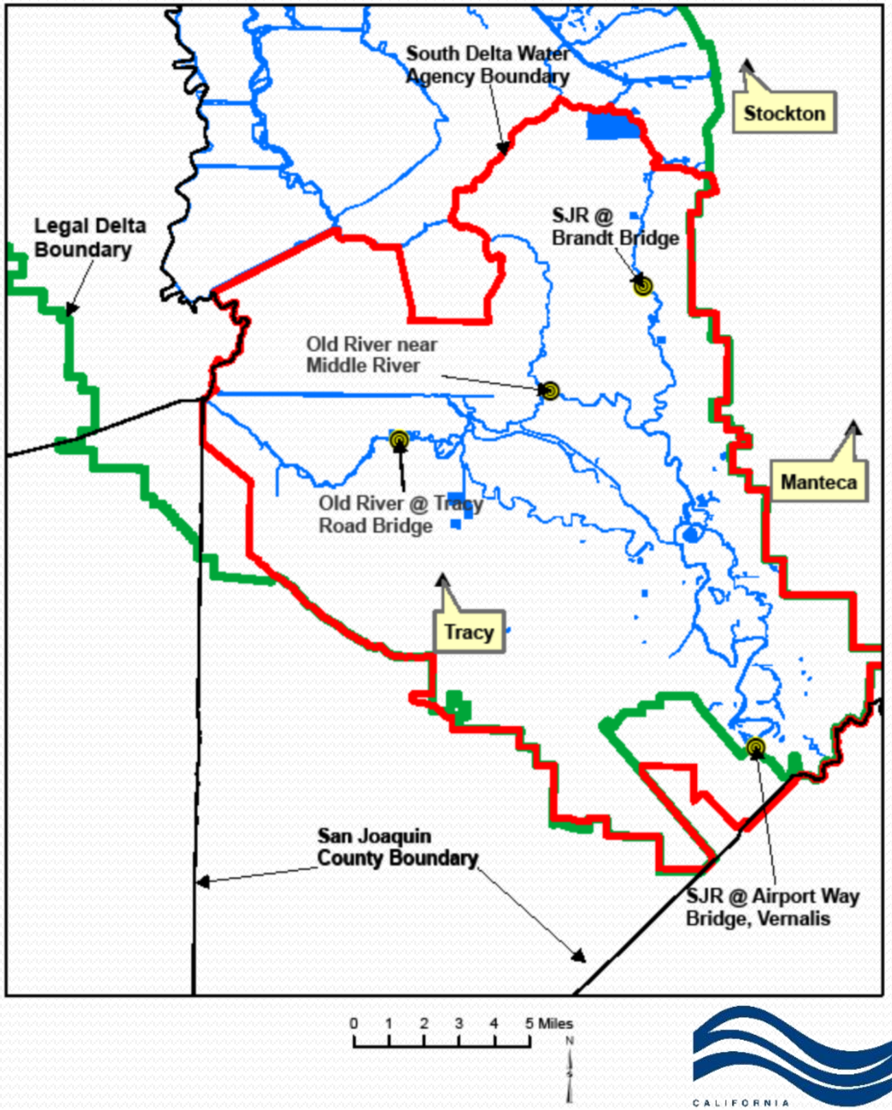
Proposed LSJR Flow Objective

- Adaptive Implementation
  - Adjustments within the 30% - 50% range
  - Adjustments within Feb - June period
  - Flow shifting to avoid temperature impacts in fall
- Stanislaus, Tuolumne, and Merced (STM) Working Group – implementing entity
  - Biological goals
  - Planning, monitoring, and reporting
  - Voluntary agreements

Current Southern Delta Salinity Objective

- April through August: 0.7 millimhos per centimeter (mmhos/cm) EC
  - based on the salt sensitivity and growing season of beans
- September through March: 1.0 mmhos/cm EC
  - based on the growing season and salt sensitivity of alfalfa during the seedling stage
- 4 Salinity compliance stations within the south Delta:
  - San Joaquin River at Vernalis
  - San Joaquin River at Brandt Bridge
  - Old River at Middle River
  - Old River at Tracy Road Bridge.



Hoffman Report, Figure 1.1.

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Proposed Southern Delta Salinity Objective

- Year round objective of 1.0 deciSemens per meter (dS/m) EC
- Three compliance locations changed to channel segments
  - SJR from Vernalis to Brandt Bridge
  - Middle River from Old River to Victoria Canal
  - Old River/Grant Line Canal from Head of Old River to West Canal
- Continued conditions in USBR and DWR's water rights
  - USBR - 0.7 EC at Vernalis April - Aug; 1.0 EC Sep - March
  - DWR & USBR - 1.0 EC year round in the interior Delta locations
  - DWR & USBR - Continued operations of agricultural barriers or other reasonable measures to address impacts of SWP/CVP operations on water levels and flow conditions

Proposed Southern Delta Salinity Objective

- Other Requirements
  - Comprehensive Operations Plan - Information, actions, performance goals to address SWP/CVP export operations on water levels and flow conditions affecting salinity
  - Monitoring and reporting
  - Study to characterize dynamics of water level, flow, and salinity conditions
- LSJR flow objectives would improve salinity conditions

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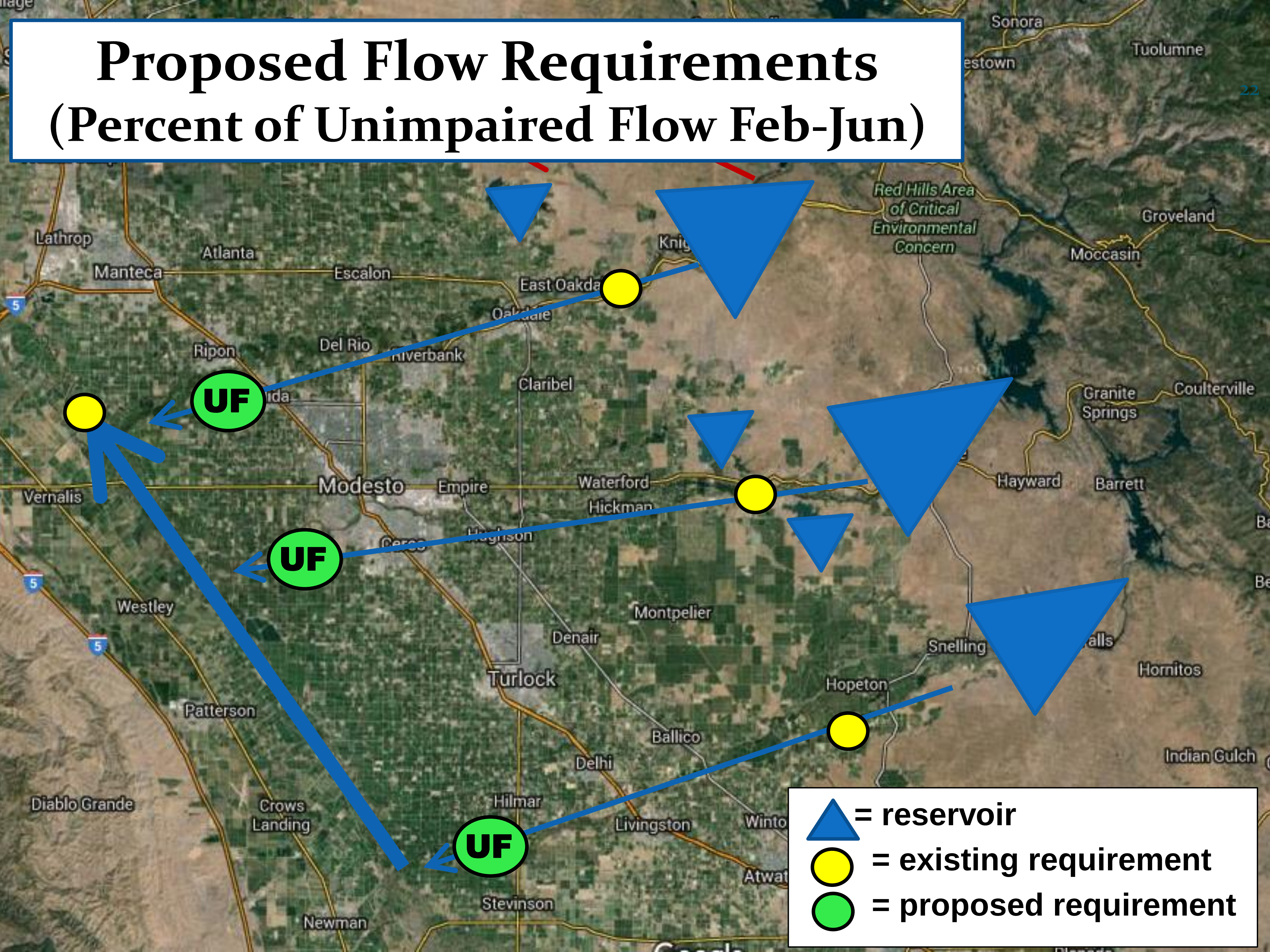
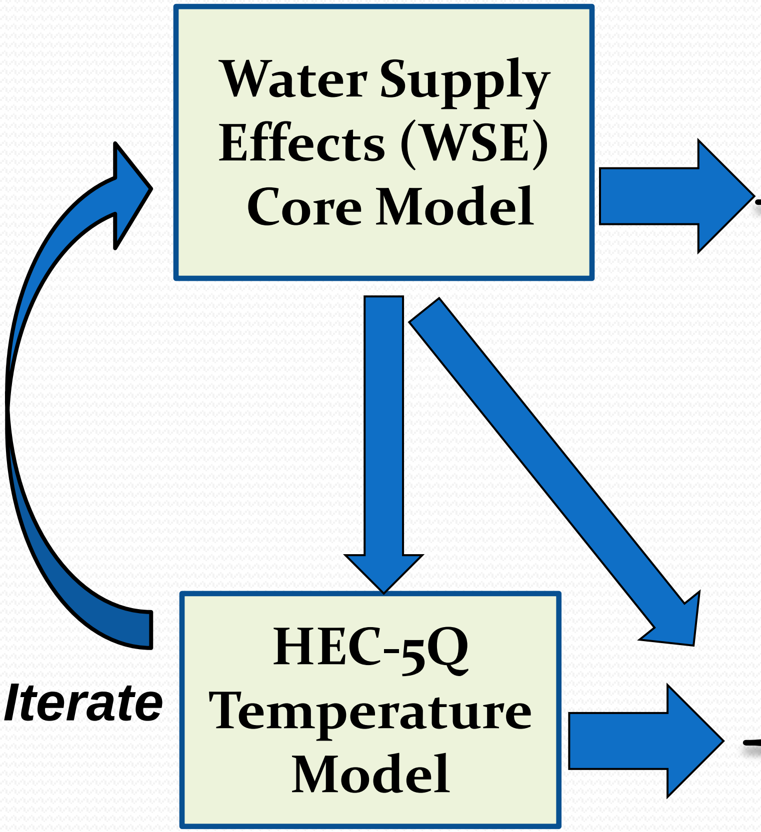
Proposed Flow Requirements
(Percent of Unimpaired Flow Feb-Jun)



Modeling Flow Chart



<u>CEQA Impacts Analysis</u>
(20%/40%/60%)

1. **Surface Water Deficit**
2. **Applied Water Needs**
3. **Groundwater Use Estimates**
4. **SWAP (StateWide Ag Production)**
5. **IMPLAN Regional Economics (IMpact analysis for PLANning)**

- **Outputs for Fish Benefits**
- **Improved Temperature**
- **Floodplain Habitat Inundation**

Programmatic Analysis

- Quantitative information from models informs physical changes that could result from the plan amendments and have the potential for quantifiable impacts on environmental resources:
  - River flows
  - Reservoir operations
  - Surface water diversions
  - Groundwater pumping
- Potential environmental impacts of these physical changes are evaluated in Chapters 5–17 of the SED
- Fish Benefits in Chapter 19

Staff Technical Workshop Part 1:
Water Supply Effects (WSE) Model Methods

Analytical Tools Used to Develop the Amendment to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary and Supporting Revised Substitute Environmental Document (SED)

December 5, 2016

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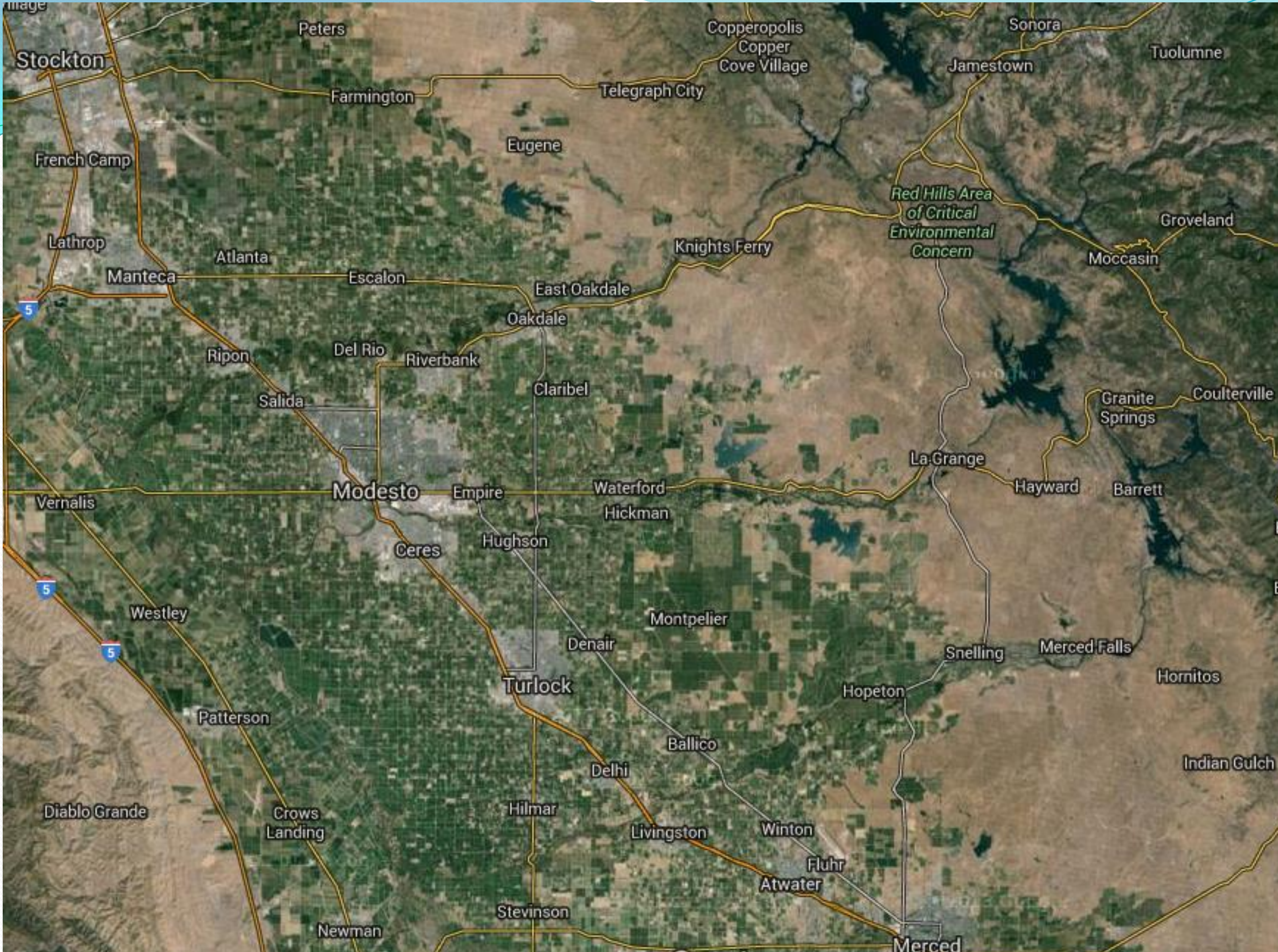
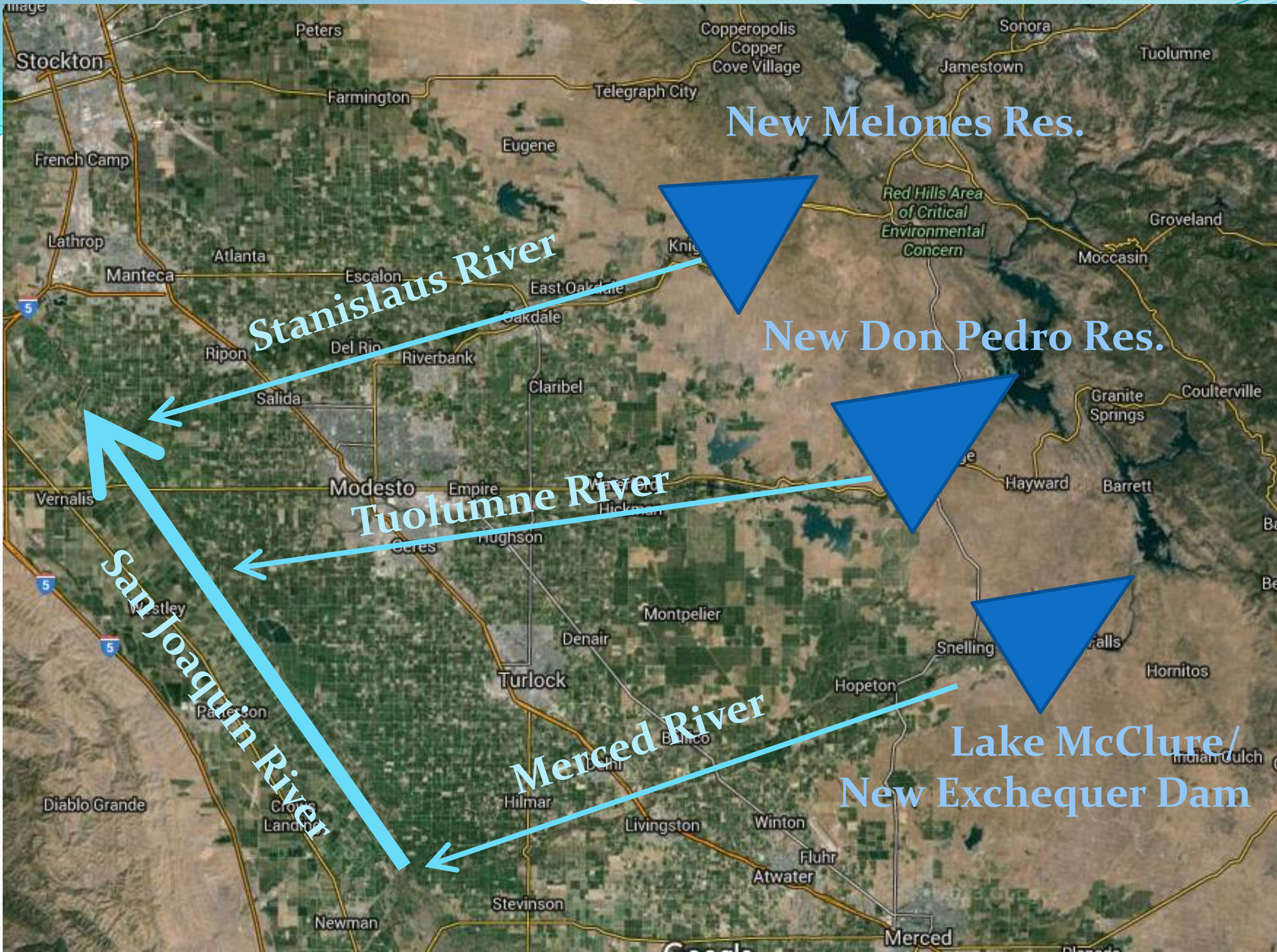
Water Supply Effects (WSE) Model

- WSE Background and CALSIM
- Changes from prior version (2012 Draft SED)
- Baseline definition and alternatives
- Instream flow requirements
- Surface water demand characterization
- Allocation of available water


Peters
Stockton
Copperopolis
Copper
Cove Village
Sonora
Tuolumne
Jamestown
Farmington
Telegraph City
Eugene
French Camp
Red Hills Area
of Critical
Environmental
Concern
Groveland
Lathrop
Atlanta
Knights Ferry
Moccasin
Manteca
Escalon
East Oakdale
5
Oakdale
Ripon
Del Rio
Riverbank
Claribel
Salida
Granite
Springs
Coulterville
La Grange
Modesto
Empire
Waterford
Hayward
Barrett
Vernalis
Hickman
Hughson
Ceres
5
Westley
Montpelier
5
Denair
Snelling
Merced Falls
Turlock
Hornitos
Hopeton
Patterson
Ballico
Delhi
Indian Gulch
Diablo Grande
Crows
Landing
Hilmar
Livingston
Winton
Fluhr
Atwater
Stevinson
Newman
Merced


New Melones Res.
Stanislaus River
New Don Pedro Res.
Tuolumne River
Lake McClure/
New Exchequer Dam
Merced River
San Joaquin River
Stockton
Peters
Copperopolis
Copper
Cove Village
Sonora
Tuolumne
Jamestown
Farmington
Telegraph City
Eugene
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Diablo Grande
Hilmar
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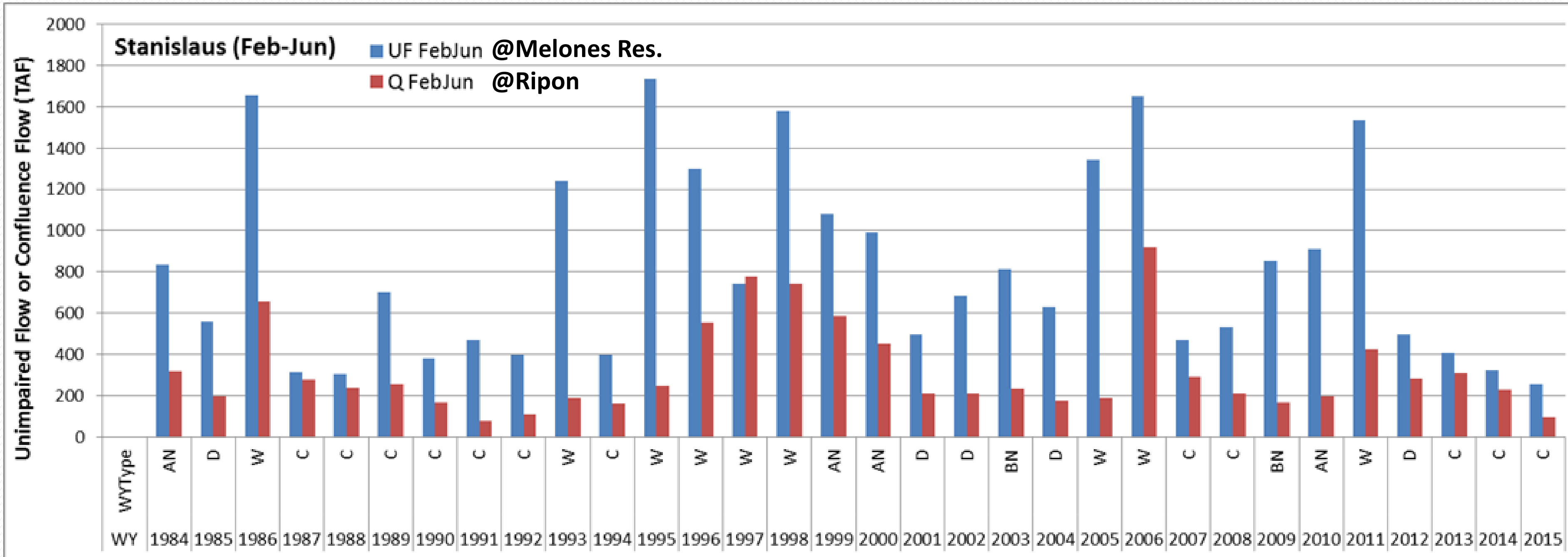
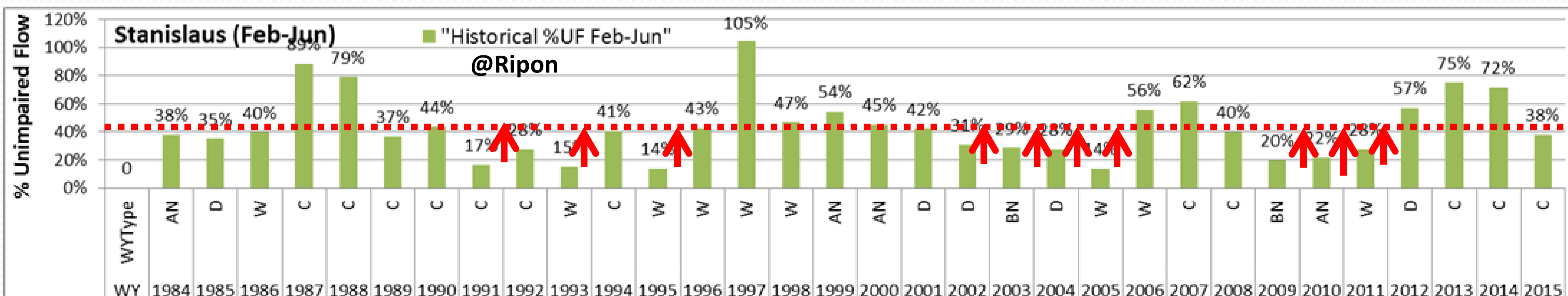
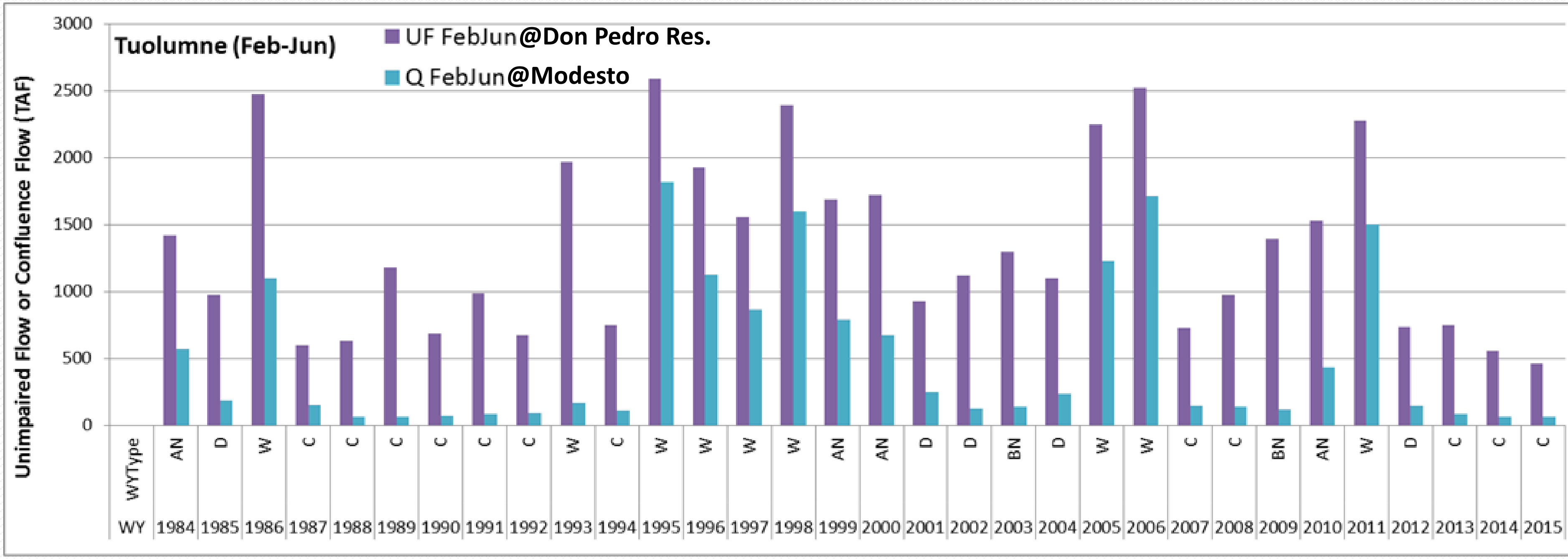
Winton
Fluhr
Atwater
Stevinson
Newman
Merced

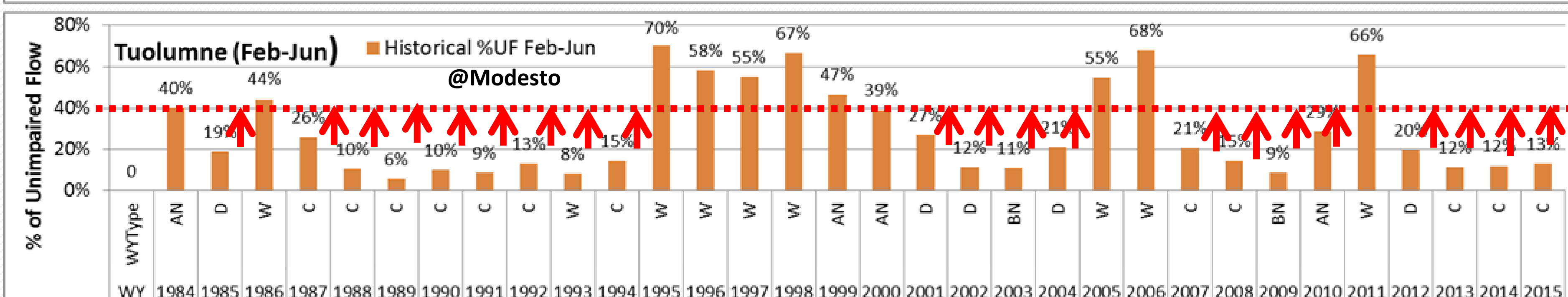
Stanislaus Historical Streamflows



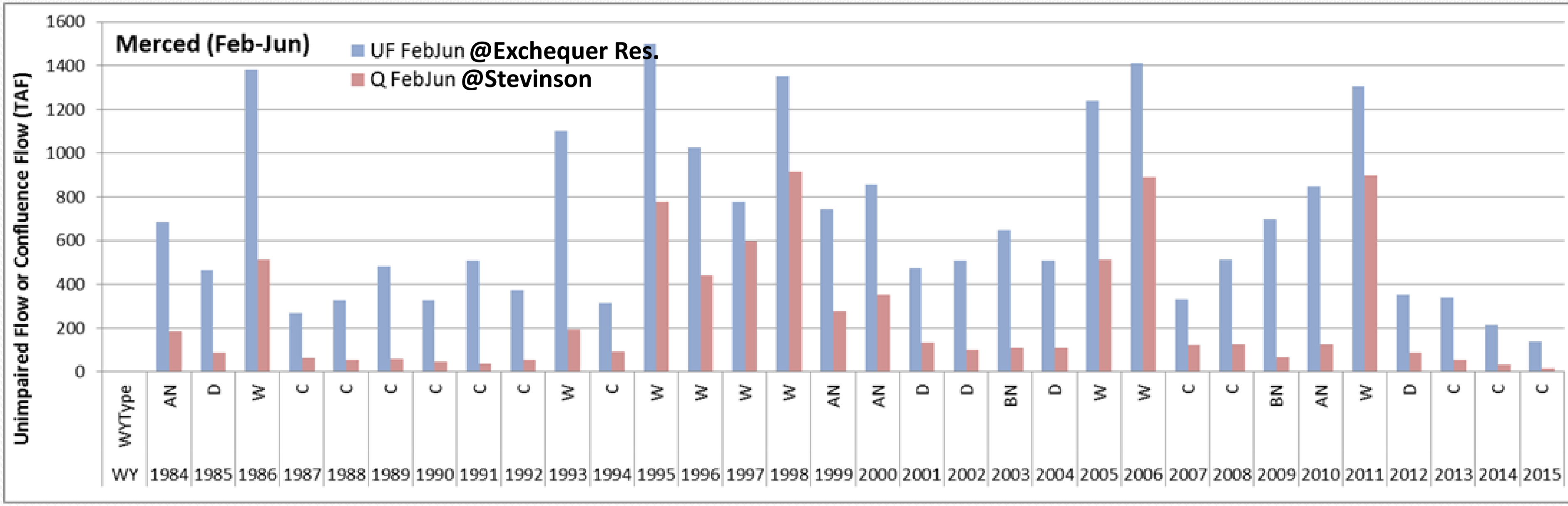


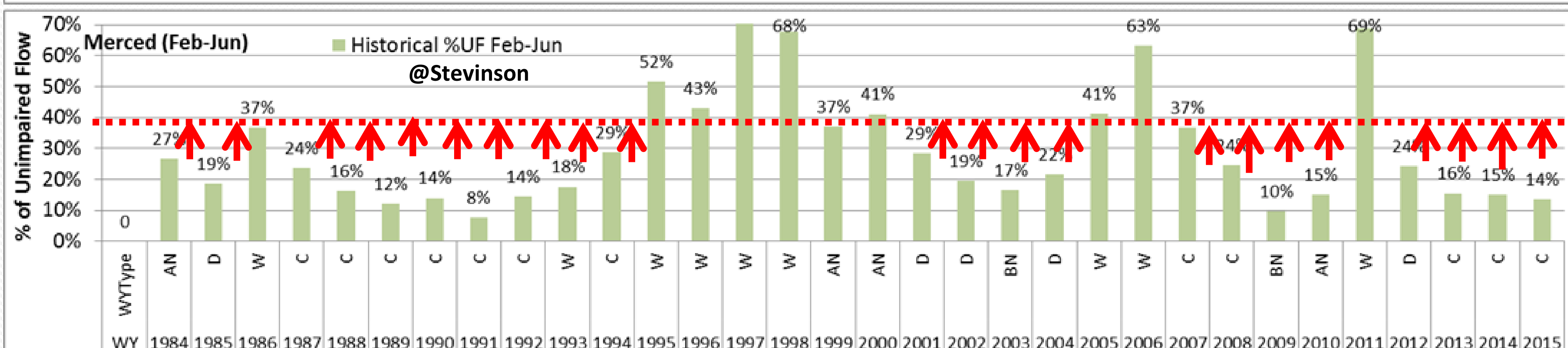
Tuolumne Historical Streamflows





Merced Historical Streamflows





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WSE = Water Supply Effects Model

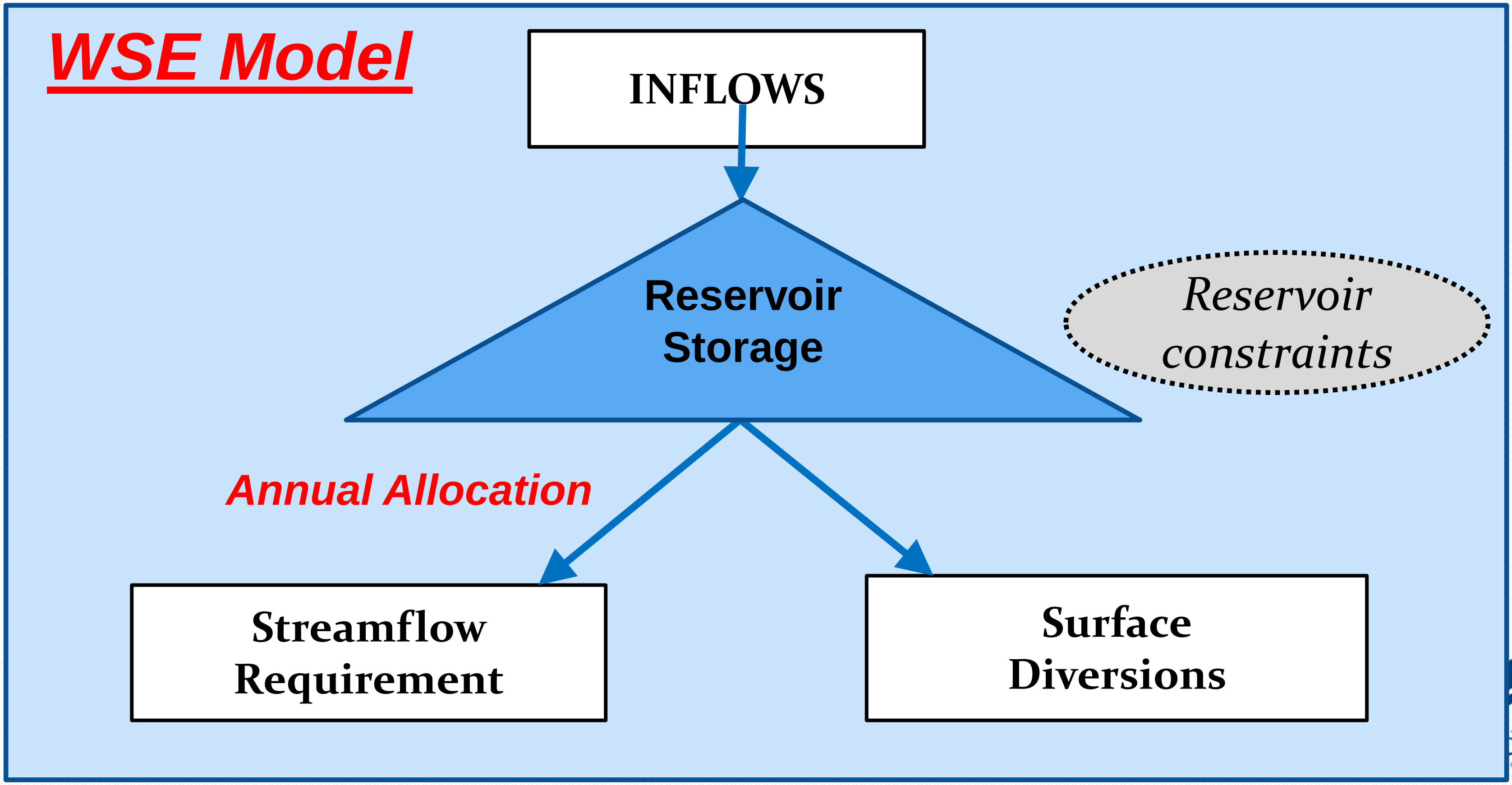
- Excel spreadsheet to evaluate %UF flow alternatives
- Uses CALSIM mass-balance framework
- Water Supply Effects of Unimpaired Flow
  - (20% / 40% / 60%) vs. Baseline Scenario
- Unimpaired flow is not same as inflow!
  - %UF is an index of water supply at the rim dams

WSE = Water Supply Effects Model

- Allocates water based on demand and availability
  - Growing season: March-September
  - Water Availability:
    - Major Tributary Inflows, Reservoir Storage
  - Reservoir Constraints:
    - Carryover storage guidelines
      - End-of-September Guideline, Percent Draw from Storage
    - Minimum percent allocation
    - Drought refill constraint
      - Limits diversions when high inflow after low storage

WSE = Water Supply Effects Model

- Allocates surface water based on demand and availability



Modeling Flow Chart

Water Supply Effects (WSE) Core Model

CEQA Impacts Analysis (20%/40%/60%)

1. **Surface Water Deficit**
2. **Applied Water Needs**
3. **Groundwater Use Estimates**
4. **SWAP (StateWide Ag Production)**
5. **IMPLAN Regional Economics (IMpact analysis for PLANning)**

Iterate

HEC-5Q Temperature Model

- **Outputs for Fish Benefits**
- **Improved Temperature**
- **Floodplain Habitat Inundation**

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CALSIM II and WSE Model Development

CALSIM II
"San Joaquin River Basin"

- CALSIM: planning mass-routing framework model
  - CA Dept. of Water Resources and USBR joint development
- SJR representation peer reviewed 2005
- 82 years of monthly record
  - Water Years 1922-2003
- Inflow boundaries at each rim reservoir
- Diversion demands, Allocations, Return Flows
- Local hydrology inflows +/-
- *Scenarios based on user specification*

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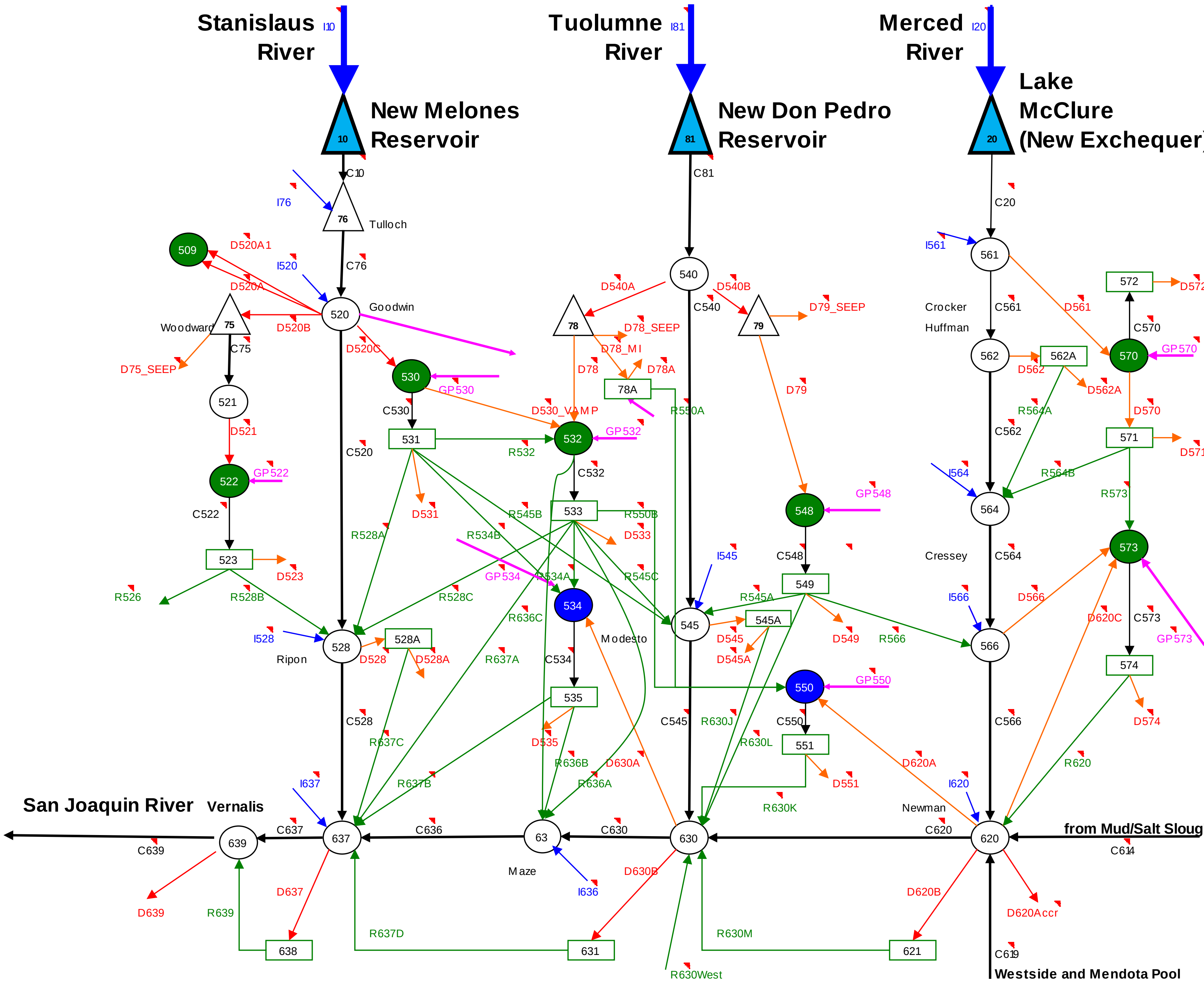
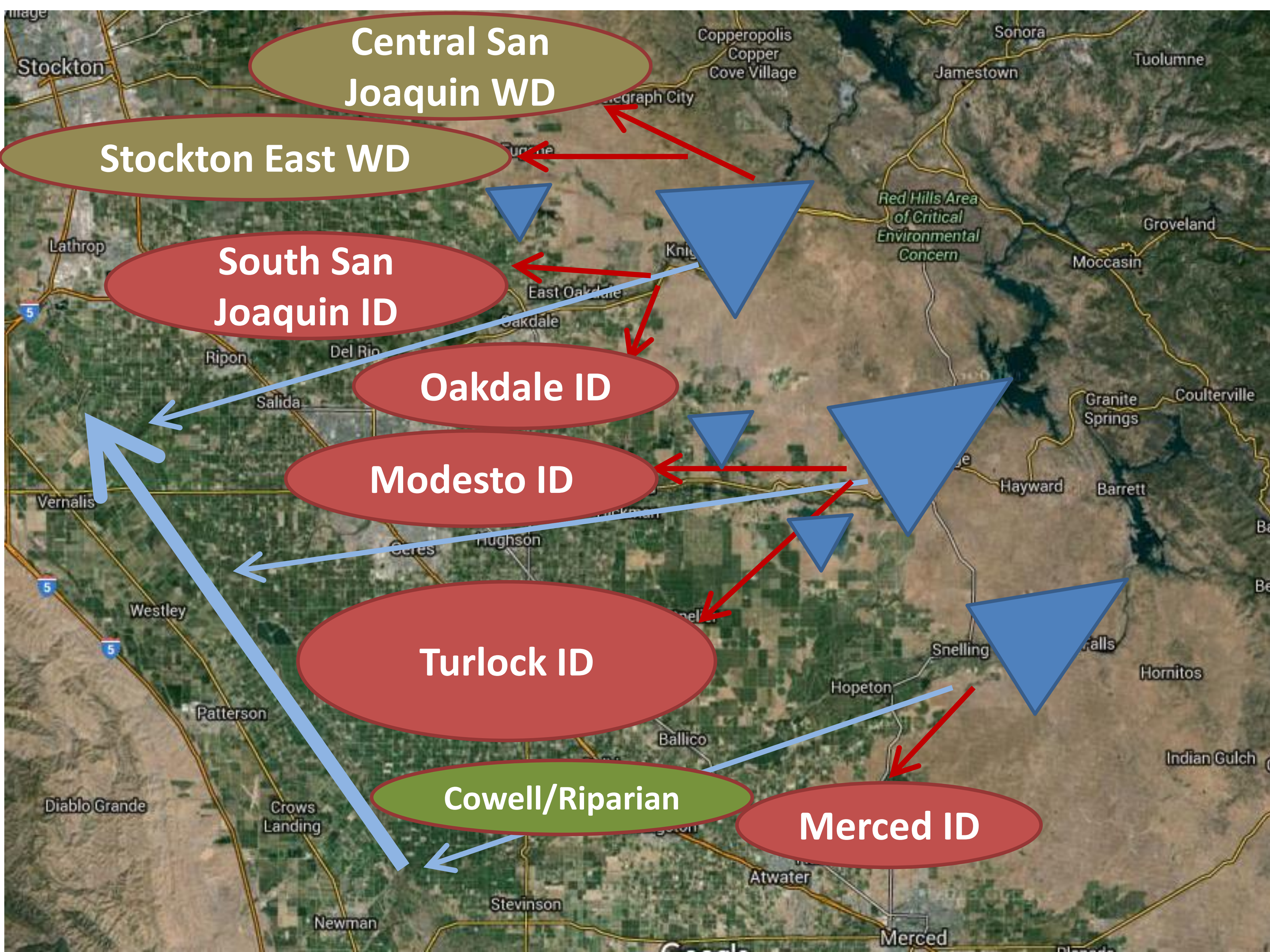
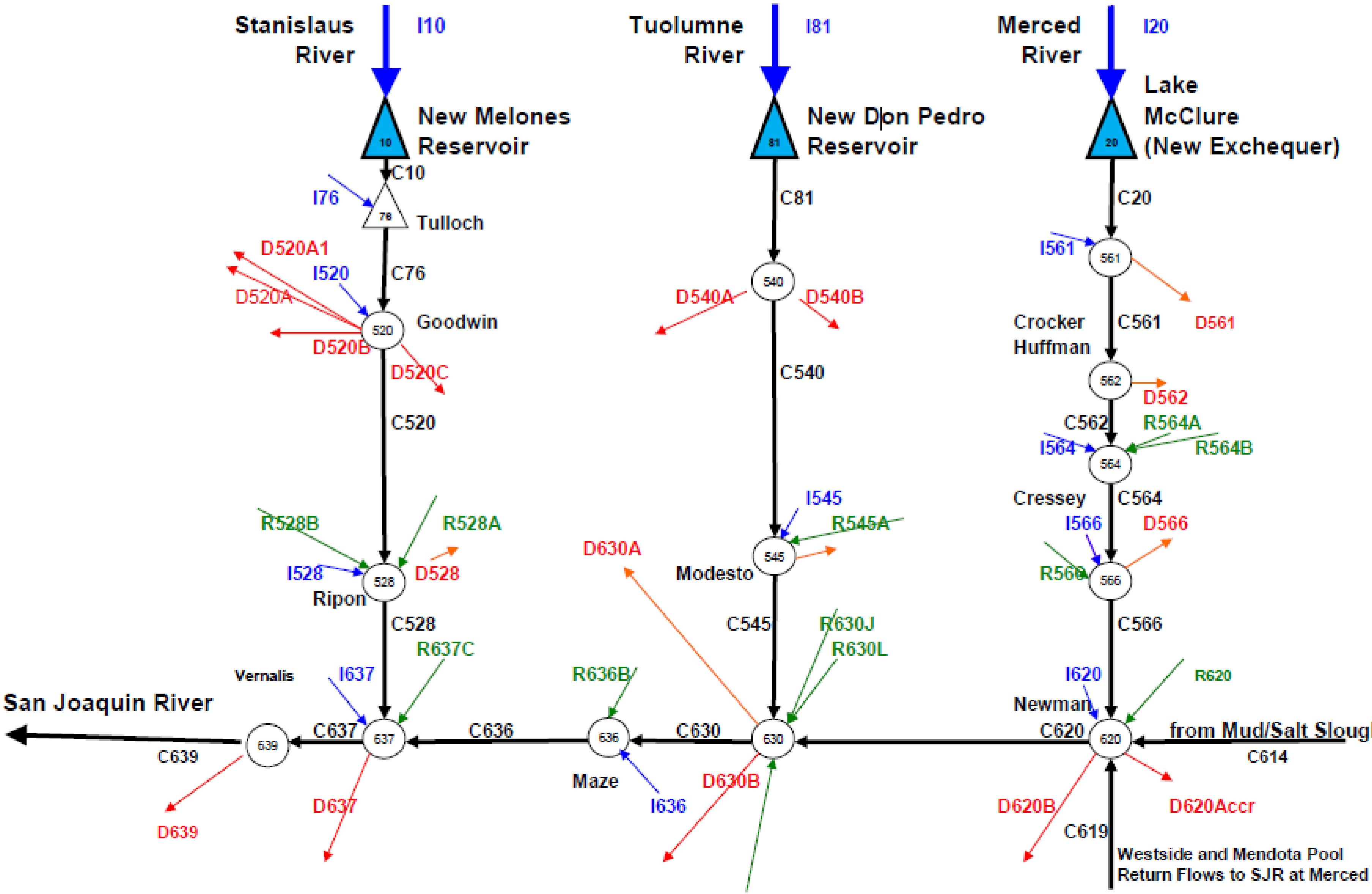
CALSIM SAN JOAQUIN RIVER SCHEMATIC





Central San Joaquin WD
Stockton East WD
South San Joaquin ID
Oakdale ID
Modesto ID
Turlock ID
Cowell/Riparian
Merced ID
Stockton
Lathrop
Ripon
Salida
Del Rio
Oakdale
East Oakdale
Vernalis
Westley
Patterson
Ceres
Hughson
Hopeton
Snelling
Ballico
Crows Landing
Diablo Grande
Stevinson
Newman
Atwater
Merced
Copperopolis
Copper Cove Village
Sonora
Jamestown
Tuolumne
Red Hills Area of Critical Environmental Concern
Groveland
Moccasin
Granite Springs
Coulterville
Hayward
Barrett
Hornitos
Indian Gulch

SJR CALSIM II Schematic



CALSIM II Scenario Used By SWRCB

- SWRCB application for CALSIM Baseline
- Includes Vernalis Adaptive Management Program (VAMP) spring pulse flow targets
- Remainder of D-1641 Requirements at Vernalis (streamflow and salinity)
- BiOp RPA/FERC Requirements at Diversion Dams
  - Goodwin, Lagrange, Crocker-Huffman
- Includes Surface Water Demands for Irrigation Districts
  - Also minor/riparian diversions at each node

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CALSIM refinements

- DWR DRR 2009 CALSIM used for 2012 SED
- USBR 2013 CALSIM used for recirculated 2016 SED
  - VAMP pulse flows, double step
  - Biological Opinion - RPA flows on Stanislaus
  - CVP Contractor Allocations: 155 TAF

WSE refinements since 2012

- Continuous Year-round Monthly Reoperation
- Monthly CALSIM Crop Demand (CUAW)
  - Varies between wet/dry years
- Comparison of WSE Baseline vs. WSE Alternative
- Includes FERC & Cowell/Davis-Grunsky flows (Merced)
- Stanislaus 1988 Agreement OID-SSJID/USBR
- AWMP data to characterize efficiencies
  - Translate Crop Demand ←→ Total Surface Demand

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WSE Model – CALSIM Framework

B_WSE_Model_v4.16 - Microsoft Excel

B7 | 31

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1							Tributary Nodes														
2							(cfs unless otherwise noted)														
3																					
4	Calendar Date	Days per month	Calendar Month	Water Year	Water Year Type	Unimpaired Flow	New Melones Reservoir			Reservor Node 10	Tulloch Reservoir			Reservor Node 76							Flow Node 520
5						TAF	+TAF	-	TAF		+TAF	-	TAF		+TAF	-	-	-	-		
6	CD	DPM	CM	WY	WYT	SUF	I10	E10	S10	C10	I76	E76	S76	C76	I520	D520A	D520A1	D520B	D520C	520%TotD	C520
7	Oct-21	31	10	1922	W	4	31	55	951	1,252	0	10	57	1,454	0	145	0	327	185	98%	797
8	Nov-21	30	11	1922	W	6	34	24	956	464	0	4	57	460	0	103	0	142	16	100%	200
9	Dec-21	31	12	1922	W	25	49	13	982	360	3	2	57	403	0	90	0	117	0	100%	200
10	Jan-22	31	1	1922	W	35	45	12	1,003	373	3	2	57	420	0	76	0	115	0	100%	232
11	Feb-22	28	2	1922	W	107	110	23	1,110	23	22	4	57	412	2	76	0	129	0	100%	236
12	Mar-22	31	3	1922	W	103	96	34	1,185	317	8	5	59	424	1	85	0	149	0	100%	200
13	Apr-22	30	4	1922	W	170	113	53	1,146	2,506	6	8	62	2,528	0	118	0	612	293	99%	1,512
14	May-22	31	5	1922	W	495	370	94	1,332	2,889	2	15	67	2,830	0	299	0	863	388	96%	1,282
15	Jun-22	30	6	1922	W	378	374	138	1,566	2,212	0	21	67	2,198	0	458	0	978	399	96%	363
16	Jul-22	31	7	1922	W	87	92	165	1,512	2,209	0	24	67	2,185	0	501	0	989	429	96%	265
17	Aug-22	31	8	1922	W	17	44	149	1,421	2,060	0	22	67	2,038	0	385	0	952	419	97%	283
18	Sep-22	30	9	1922	W	4	31	112	1,364	1,358	0	17	63	1,400	0	227	0	597	326	97%	250
19	Oct-22	31	10	1923	AN	6	28	64	1,313	1,226	0	9	57	1,322	0	138	0	253	158	99%	774
20	Nov-22	30	11	1923	AN	16	39	27	1,326	413	1	4	57	426	0	103	0	124	0	100%	200
21	Dec-22	31	12	1923	AN	79	78	16	1,391	185	13	2	57	391	1	90	0	117	0	100%	200
22	Jan-23	31	1	1923	AN	78	78	17	1,450	304	7	2	57	409	0	76	0	115	0	100%	226
23	Feb-23	28	2	1923	AN	55	65	29	1,494	337	5	4	57	427	0	76	0	129	0	100%	229
24	Mar-23	31	3	1923	AN	77	69	45	1,450	1,791	2	6	59	1,797	0	111	0	454	206	100%	1,029
25	Apr-23	30	4	1923	AN	207	143	66	1,450	2,352	4	9	62	2,343	0	97	0	550	189	98%	1,512
26	May-23	31	5	1923	AN	356	285	101	1,534	3,157	2	14	67	3,095	0	284	0	945	424	96%	1,444
27	Jun-23	30	6	1923	AN	161	158	133	1,552	2,219	1	19	67	2,210	0	471	0	978	399	97%	363
28	Jul-23	31	7	1923	AN	73	88	163	1,494	2,219	0	24	67	2,199	0	515	0	989	429	96%	265
29	Aug-23	31	8	1923	AN	12	40	148	1,397	2,070	0	22	67	2,048	0	394	0	952	419	97%	283
30	Sep-23	30	9	1923	AN	10	38	110	1,359	1,182	0	17	64	1,224	0	195	0	499	281	97%	250

SJR_Flow(Estimate2) | SJR_Flow(Final) | CUAW-CALSIM | Stan-CALSIM | Tuol-CALSIM | Merc-CALSIM

Modeling Comparative Analysis

- Compares water supply scenarios for 82-year period
  - Baseline – ~2009 Existing Environment
    - D-1641 requirements + VAMP
    - Biological Opinion Streamflow requirements
    - FERC Streamflow requirements
  - Alternatives
    - 20% / 40% / 60% Unimpaired Flow
    - February through June
    - Shifting of flow to other months

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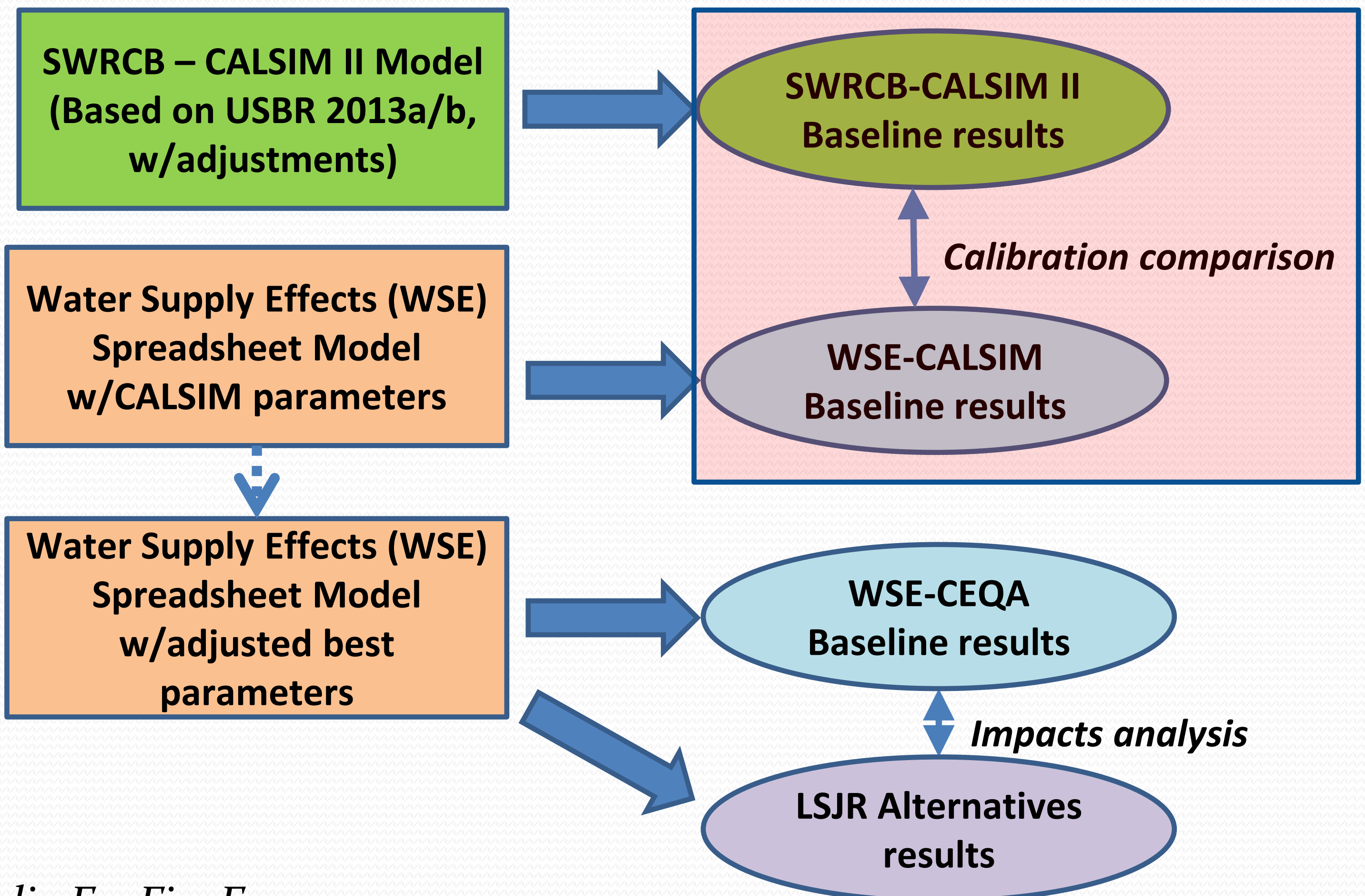
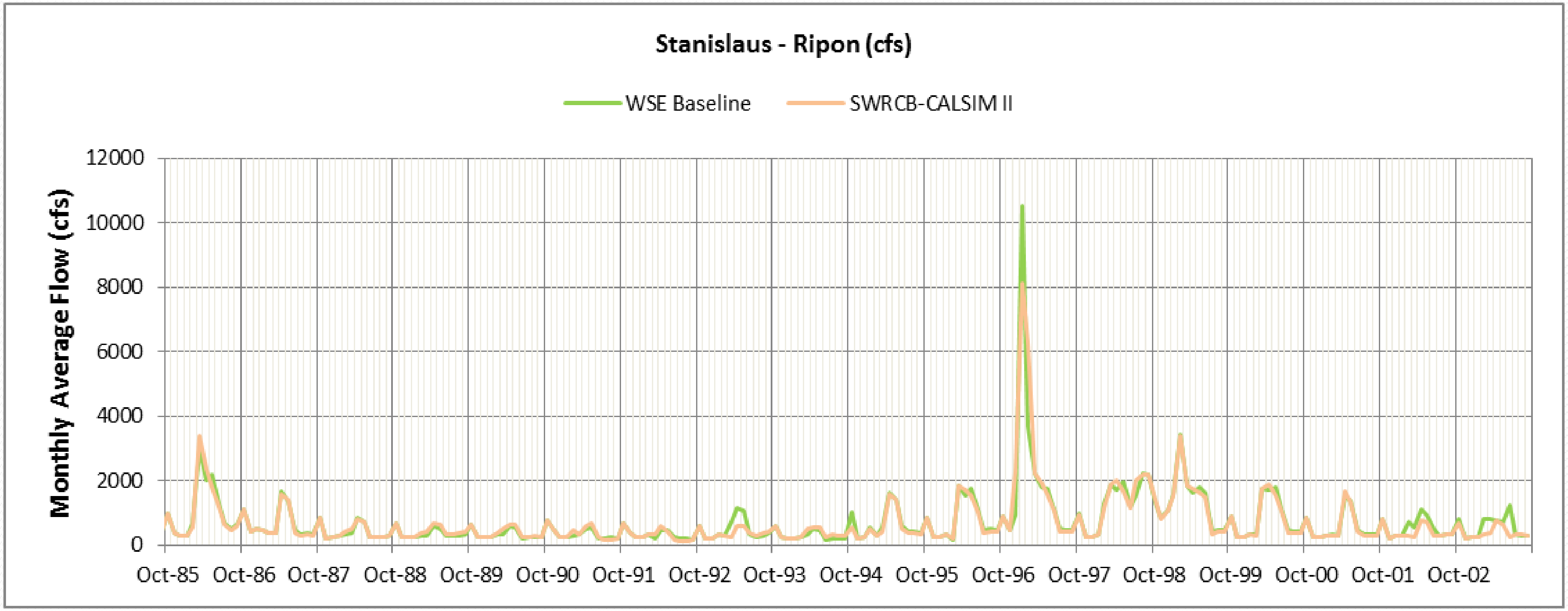
Model comparisons & scenarios



Appendix F.1, Fig. F.1.2-1

Stanislaus WSE Baseline vs. CALSIM: Monthly Streamflow (WY 1986-2003)



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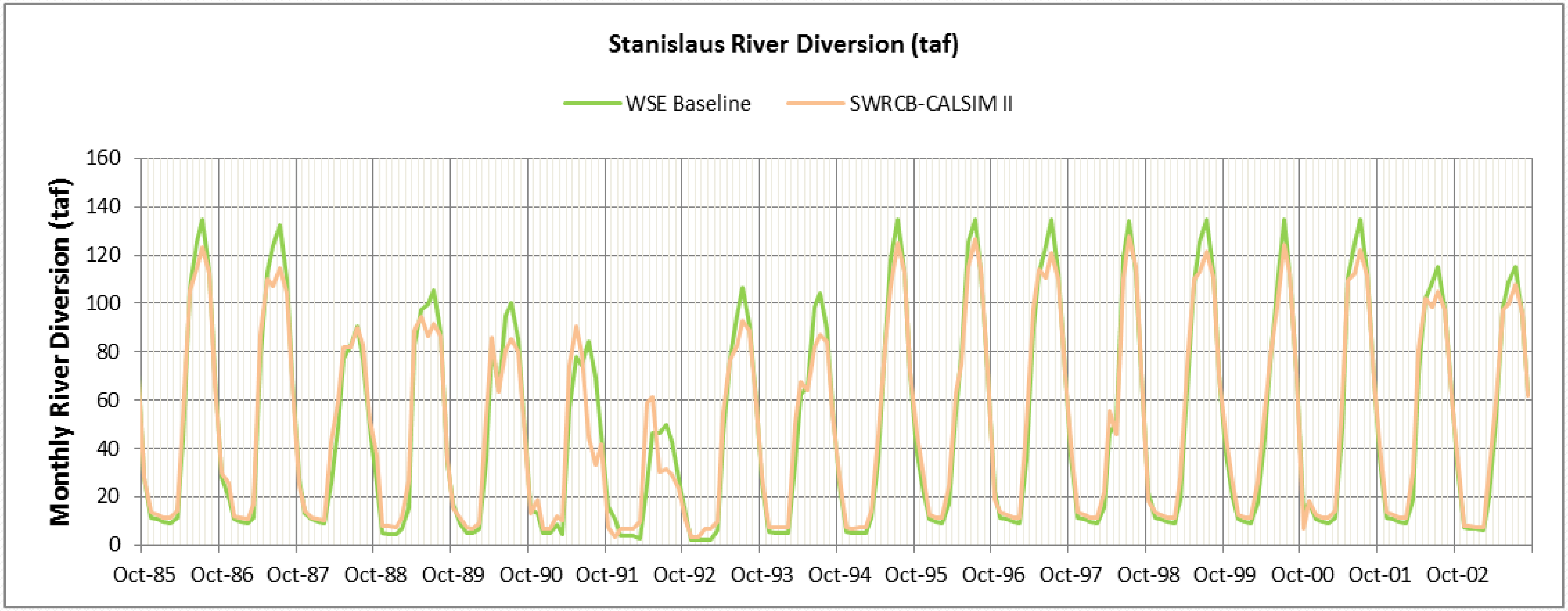
Stanislaus WSE Baseline vs. CALSIM: Monthly Total Diversions (WY 1986-2003)



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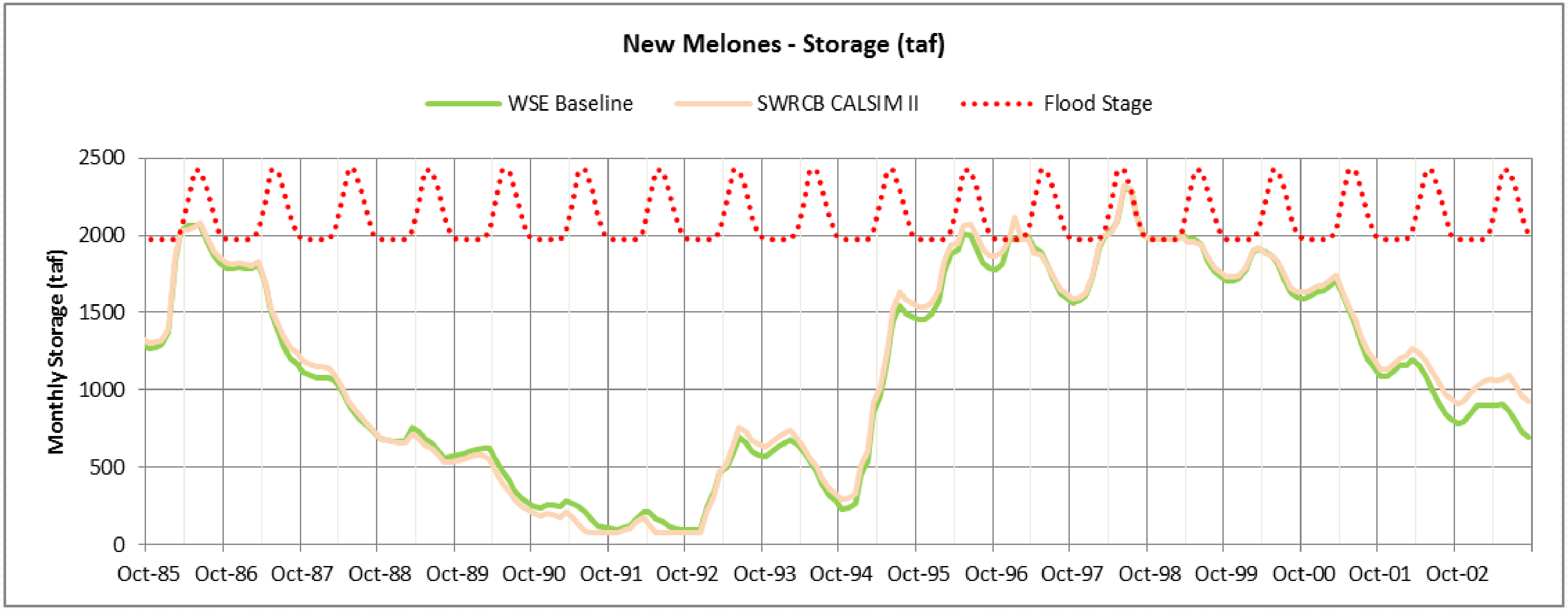
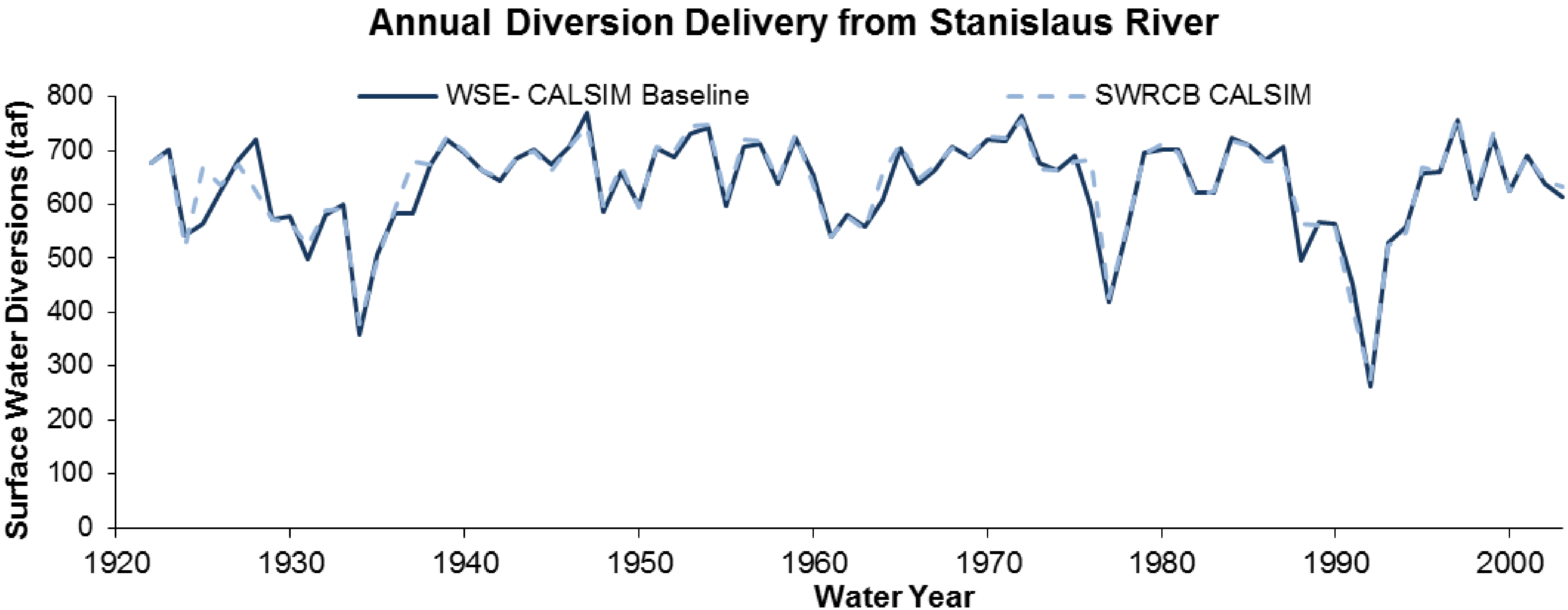
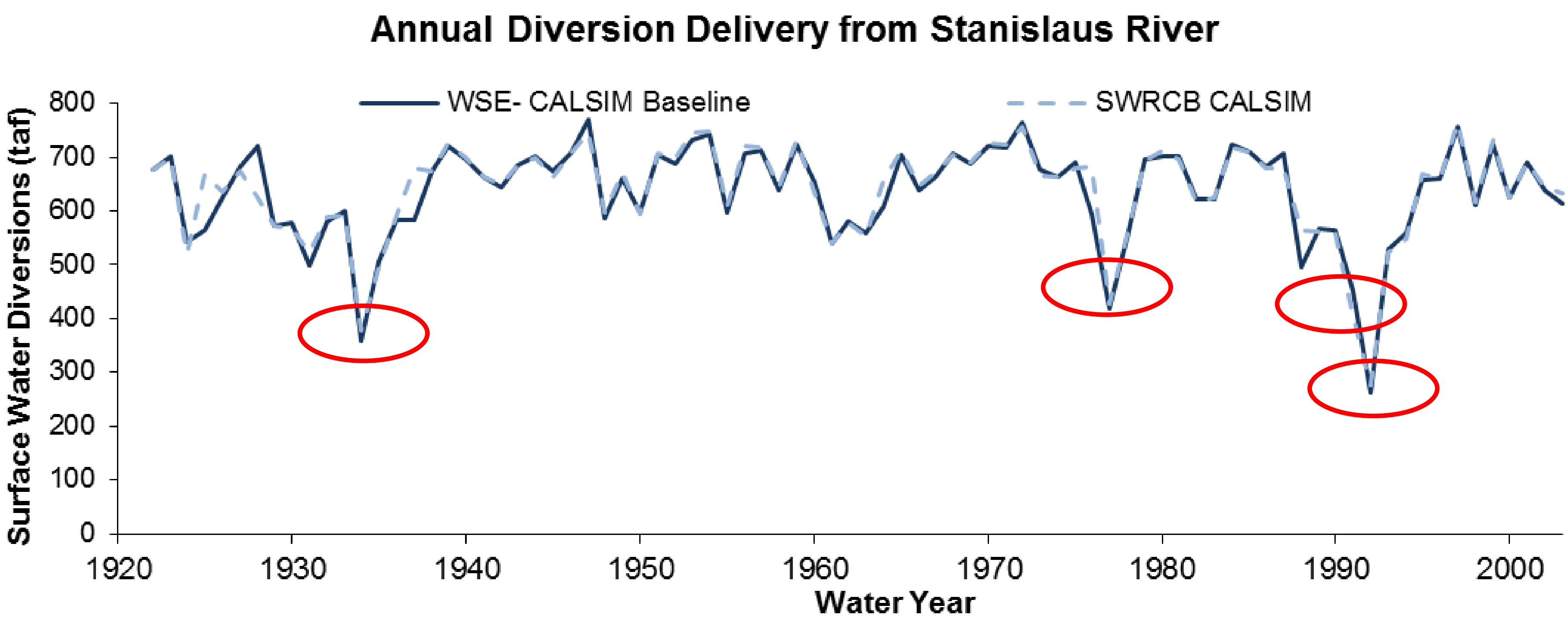
Stanislaus WSE Baseline vs. CALSIM: Monthly Reservoir Storage Condition (WY 1986-2003)



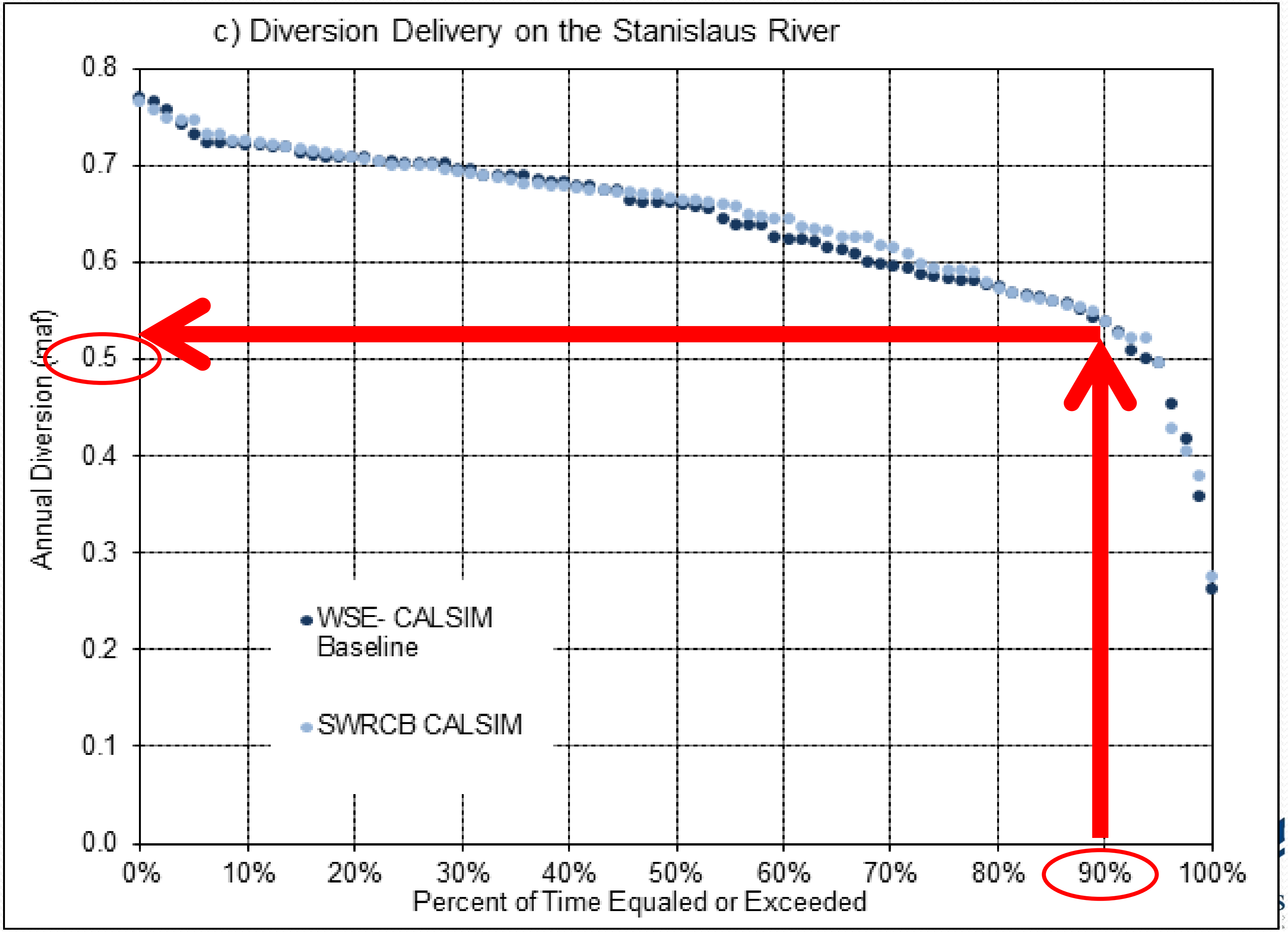
Stanislaus WSE Baseline vs. CALSIM: Annual Total Diversions (WY 1922-2003)

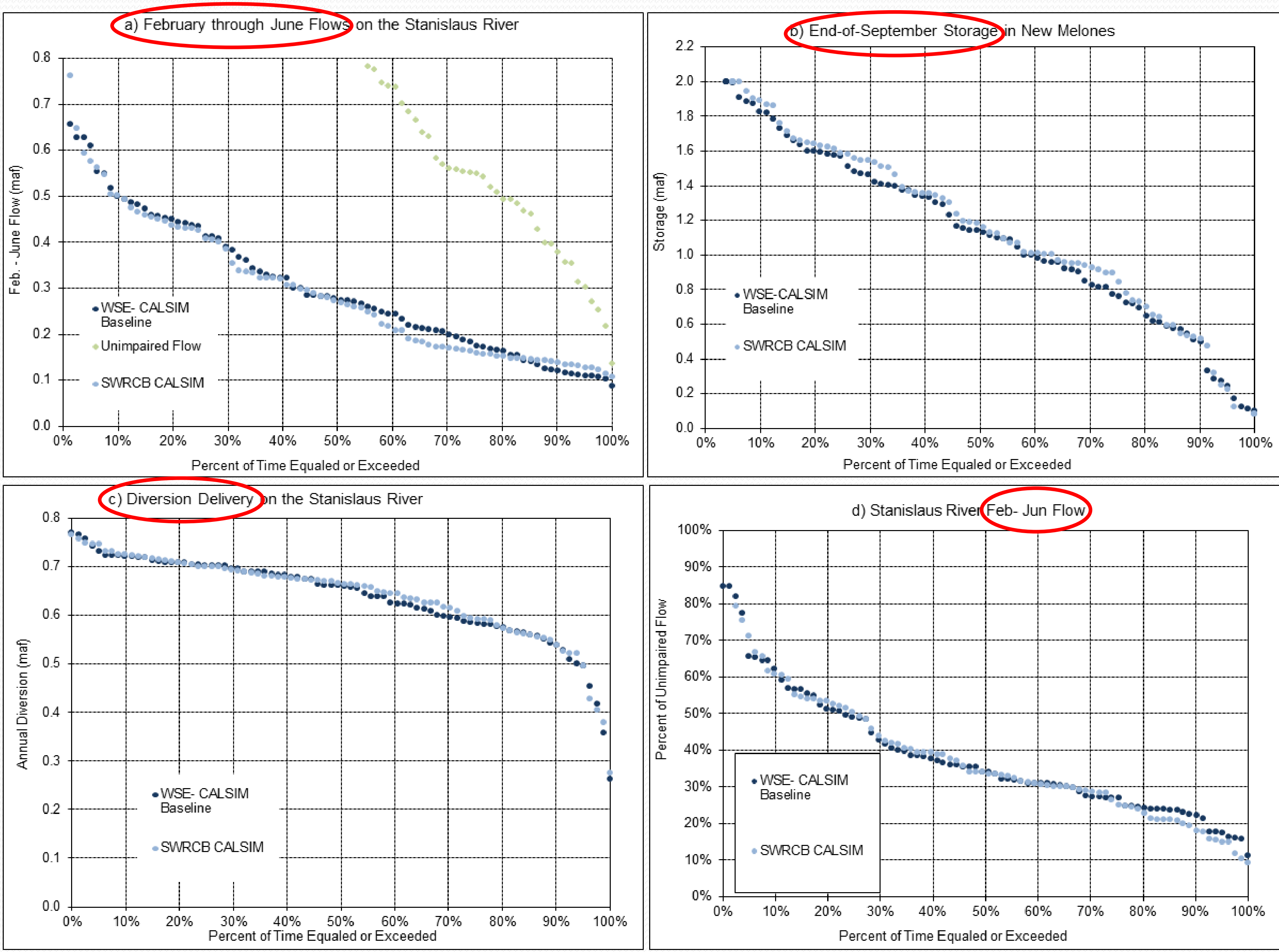


Stanislaus WSE Baseline vs. CALSIM: Annual Total Diversions



How to Read Exceedence Plots




a) February through June Flows on the Stanislaus River
Feb. - June Flow (maf)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
WSE- CALSIM Baseline
Unimpaired Flow
SWRCB CALSIM
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Equaled or Exceeded
b) End-of-September Storage in New Melones
Storage (maf)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
WSE-CALSIM Baseline
SWRCB CALSIM
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Equaled or Exceeded
c) Diversion Delivery on the Stanislaus River
Annual Diversion (maf)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
WSE- CALSIM Baseline
SWRCB CALSIM
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Equaled or Exceeded
d) Stanislaus River Feb- Jun Flow
Percent of Unimpaired Flow
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
WSE- CALSIM Baseline
SWRCB CALSIM
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Equaled or Exceeded

Instream Flow Requirements

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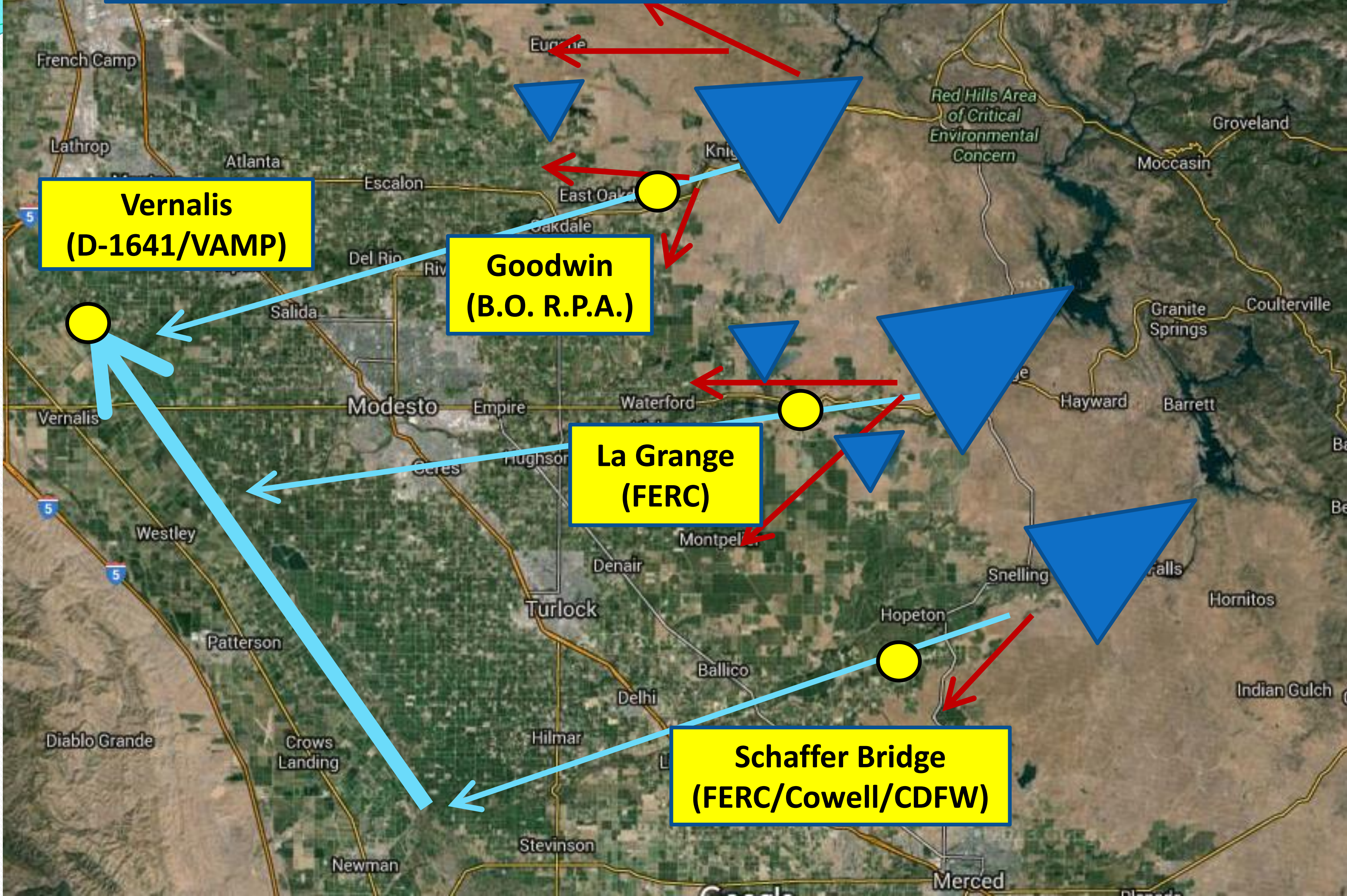
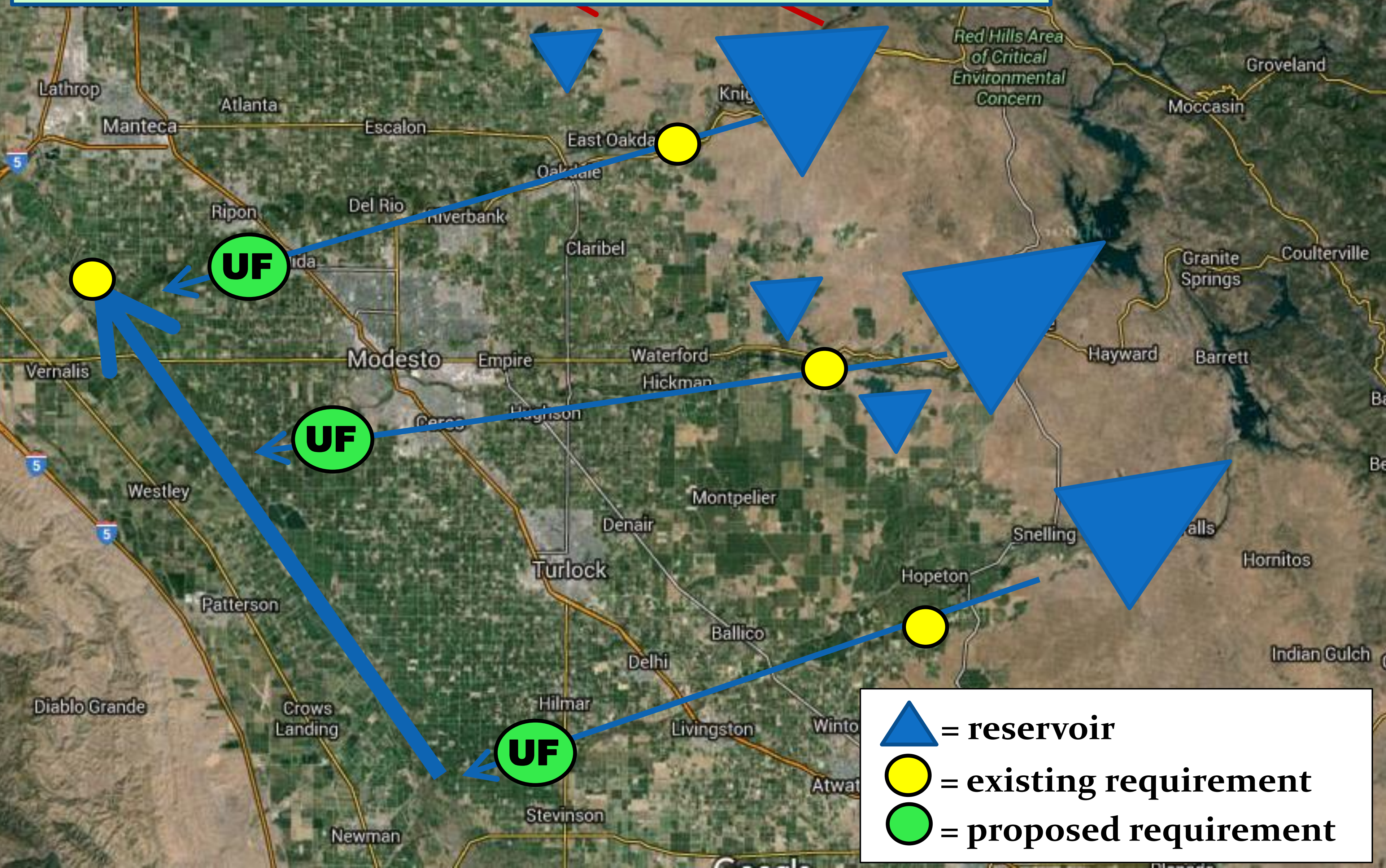
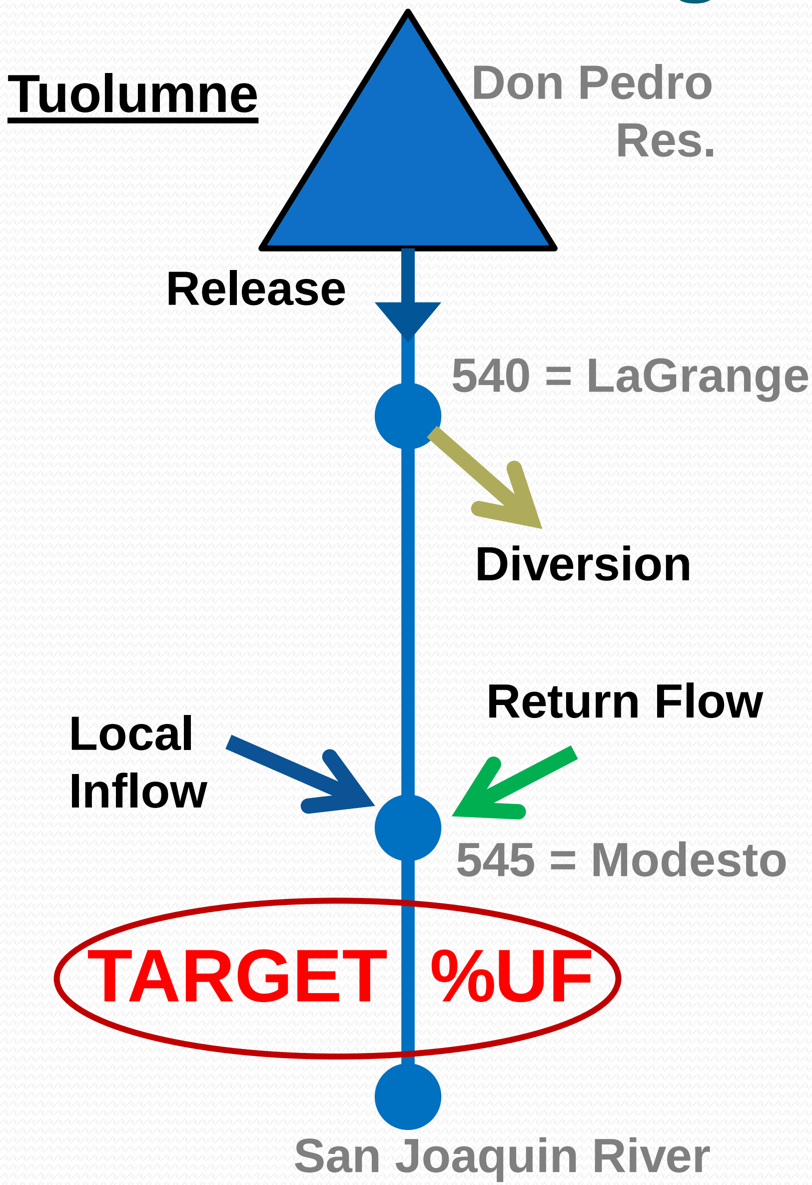
Existing Flow Requirements (Baseline)



Proposed Flow Requirements
(Percent of Unimpaired Flow Feb-Jun)

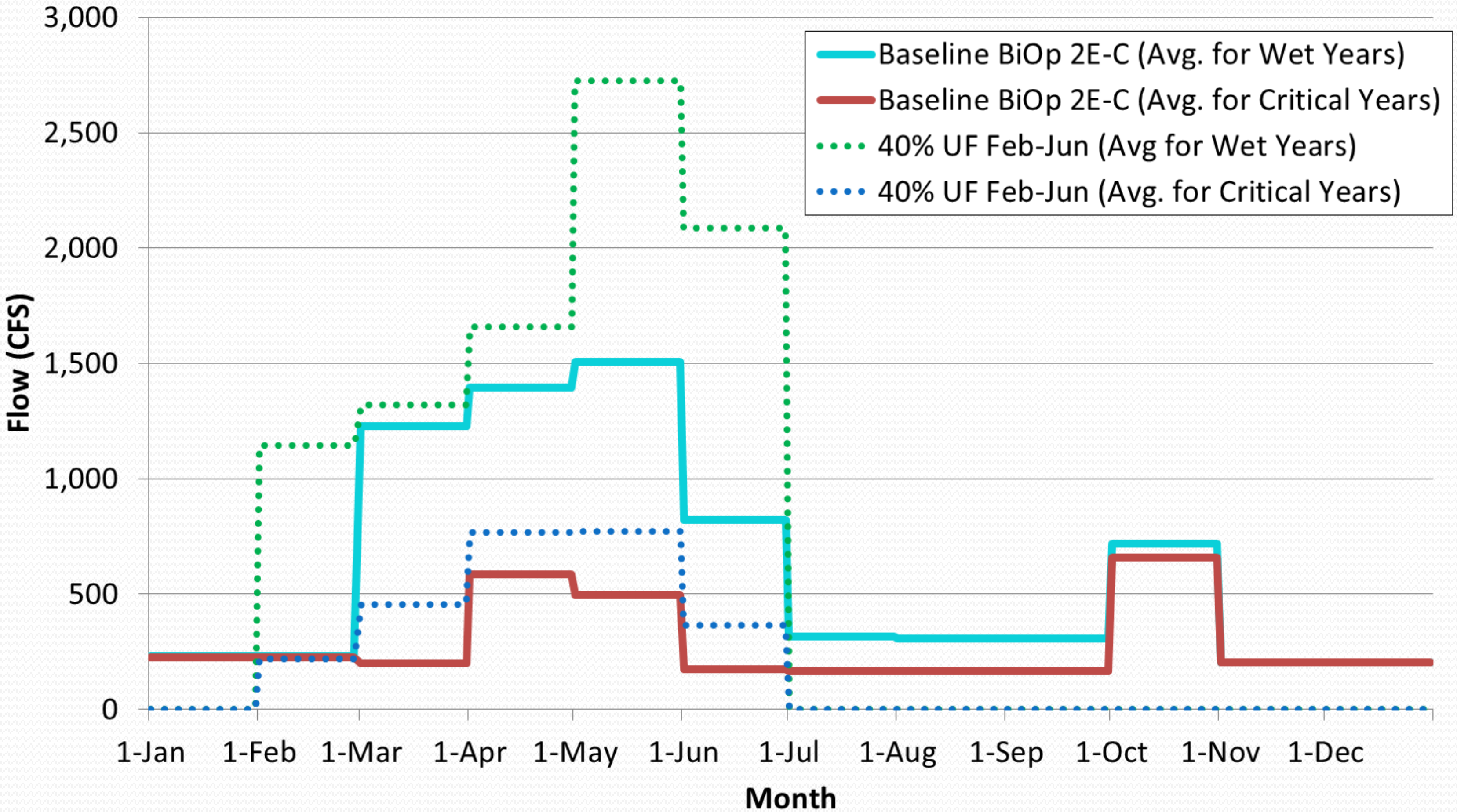


Streamflow target allocation



1. Calculate Available Water
   - from <u>All</u> Inflows (including Return and Local Inflows)
2. Calculate Diversions Available
3. Reservoir Release to meet Rarget

Stanislaus Instream Flow Requirements



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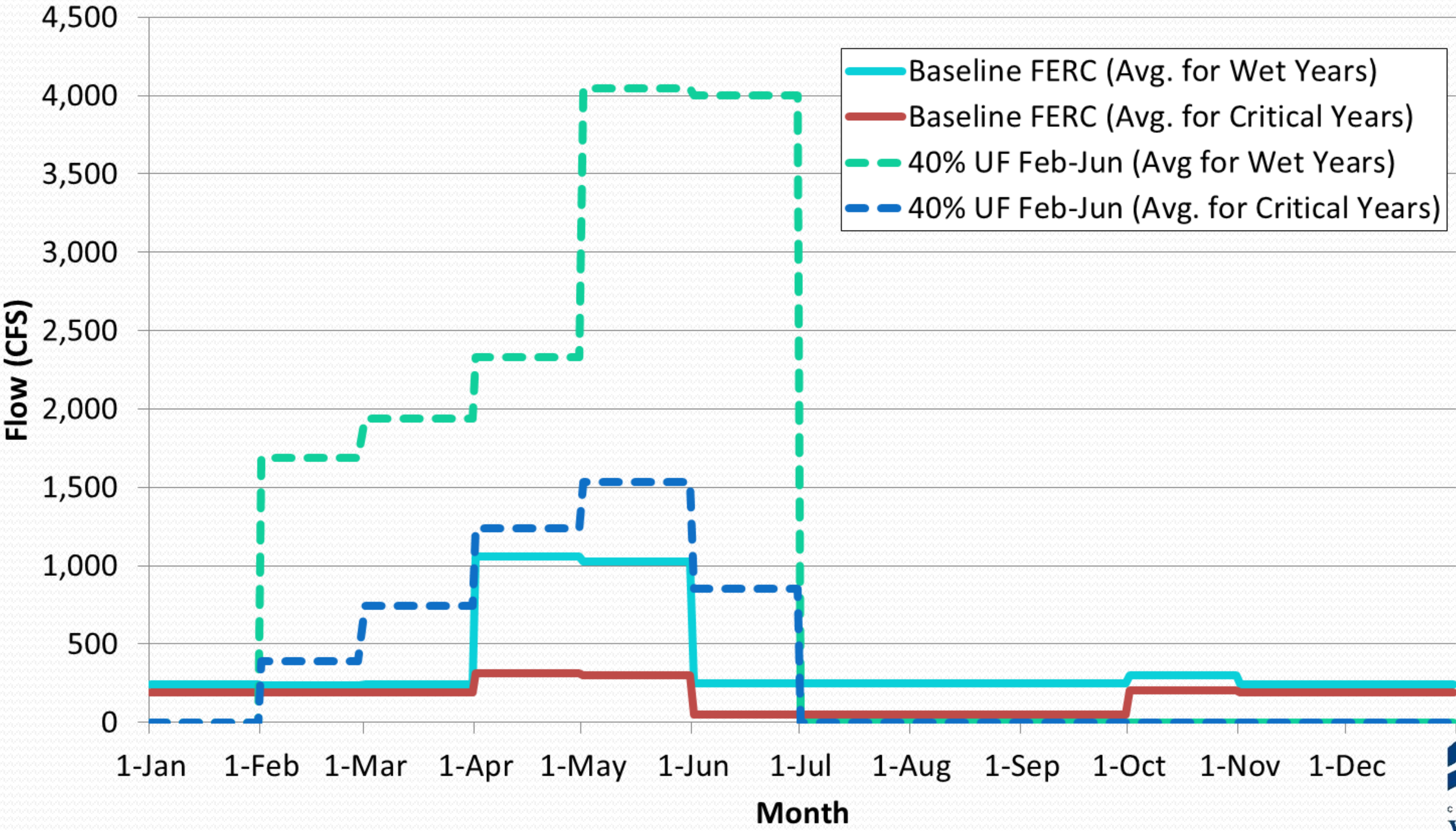
Tuolumne Instream Flow Requirements



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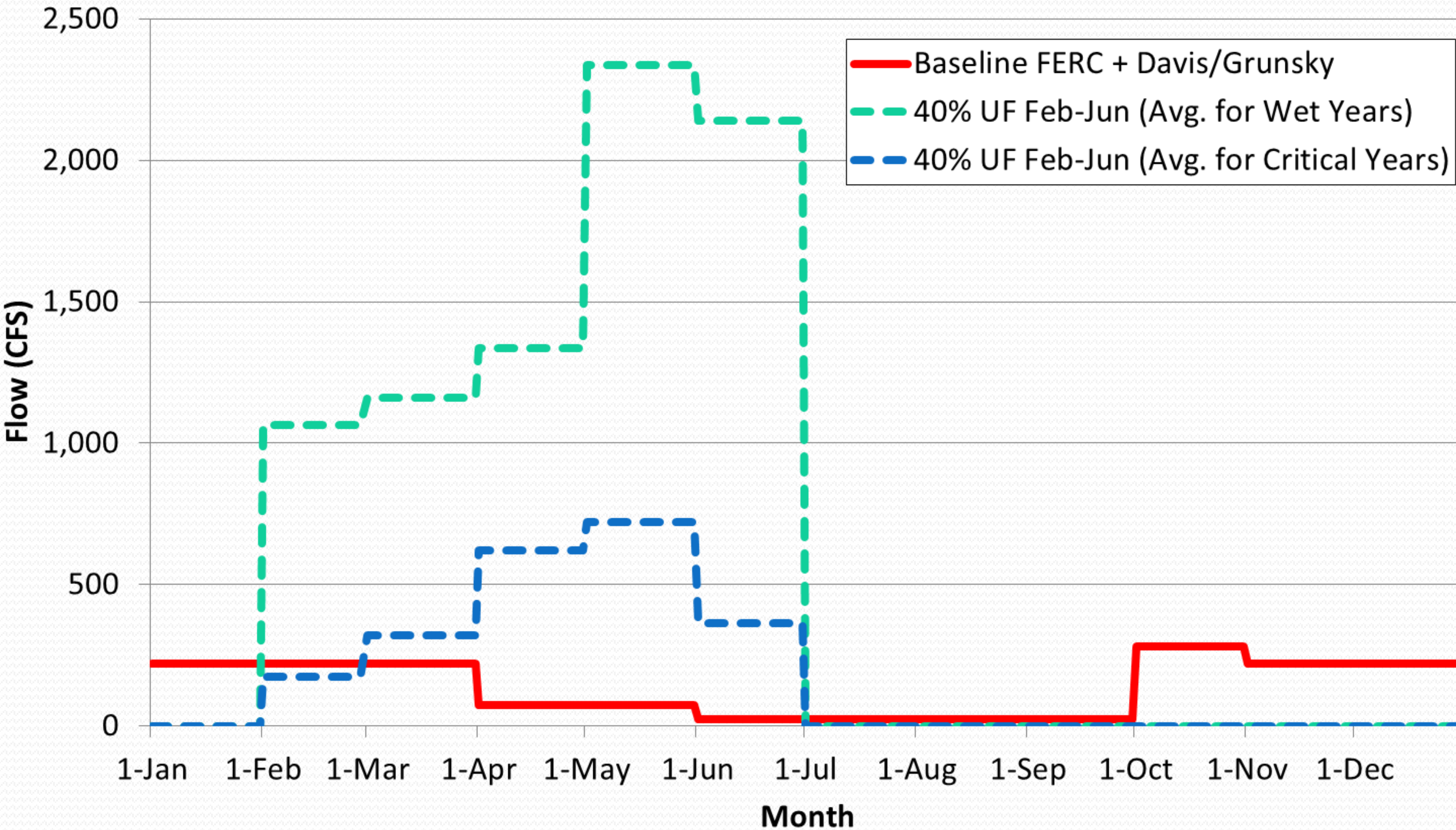
Merced Instream Flow Requirements



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VAMP Implementation

Table F.1.2-9. VAMP Minimum Pulse Flow Requirements in the SJR at Airport Way Bridge near Vernalis

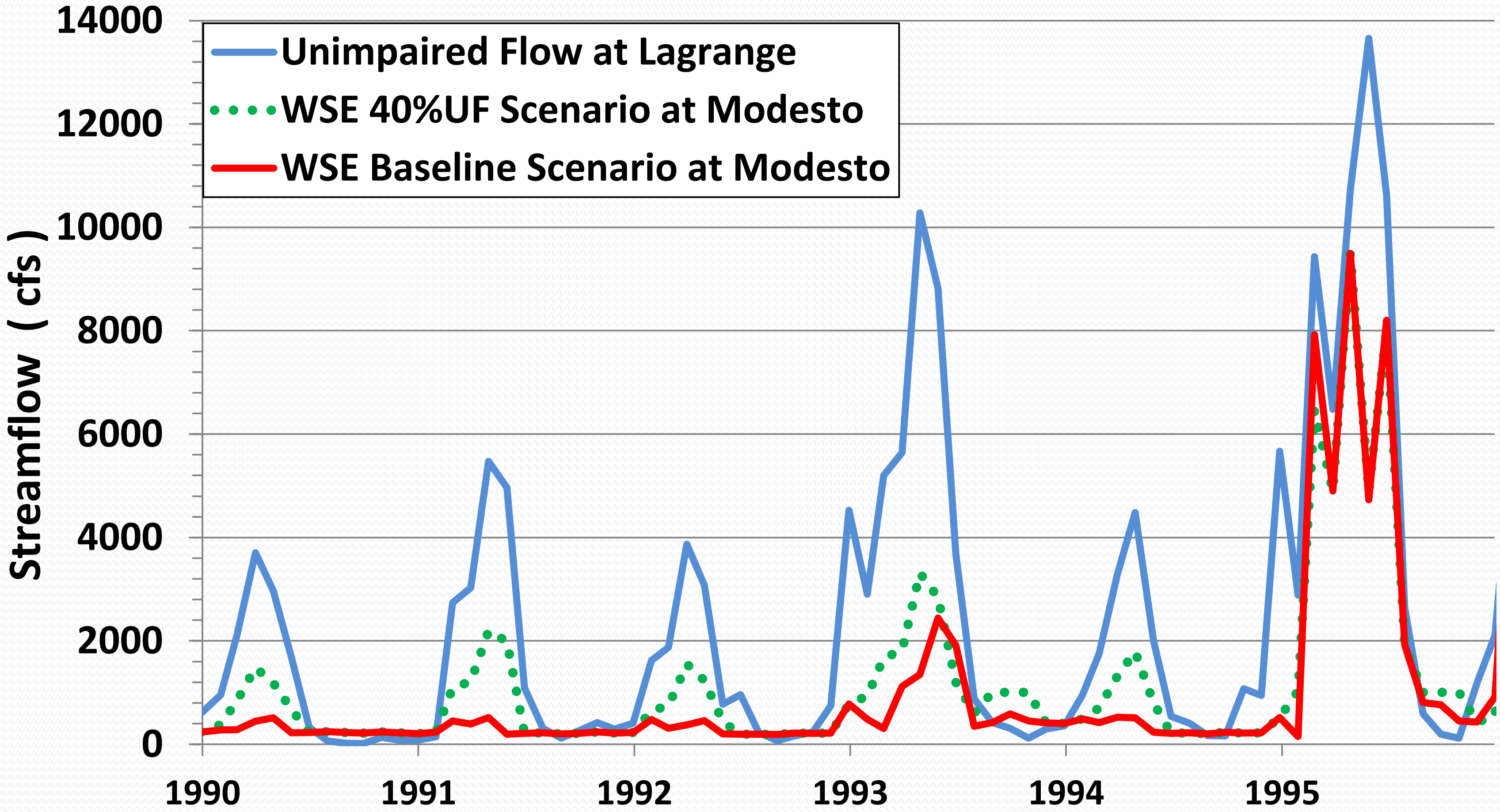
SJ 60-20-20 Water Year Type[2]	Minimum Monthly Flow (TAF) by San Joaquin Basin (60-20-20) Water Year Type		
	60-20-20 Index Indicator Value (cfs)	Existing Flow (cfs)	VAMP Pulse Target Flow (April 15–May 15)[1] (cfs)
C	1	0–1,999	2000
D	2	2,000–3,199	3,200
BN	3	3,200–4,449	4,450
AN	4	4,450–5,699	5,700
W	5	5,700–7,000	7,000

Notes:

[1] According to San Joaquin River Agreement, if the sum of current year's index and previous year's index is 7 or greater, a double step is required (next highest target level); if less than 4, no target is required (USBR and SJRGA 1999).

[2] San Joaquin Valley water year type index (60-20-20) as defined by D-1641 (SWRCB 2000).

Tuolumne River Flows (1990-1995)



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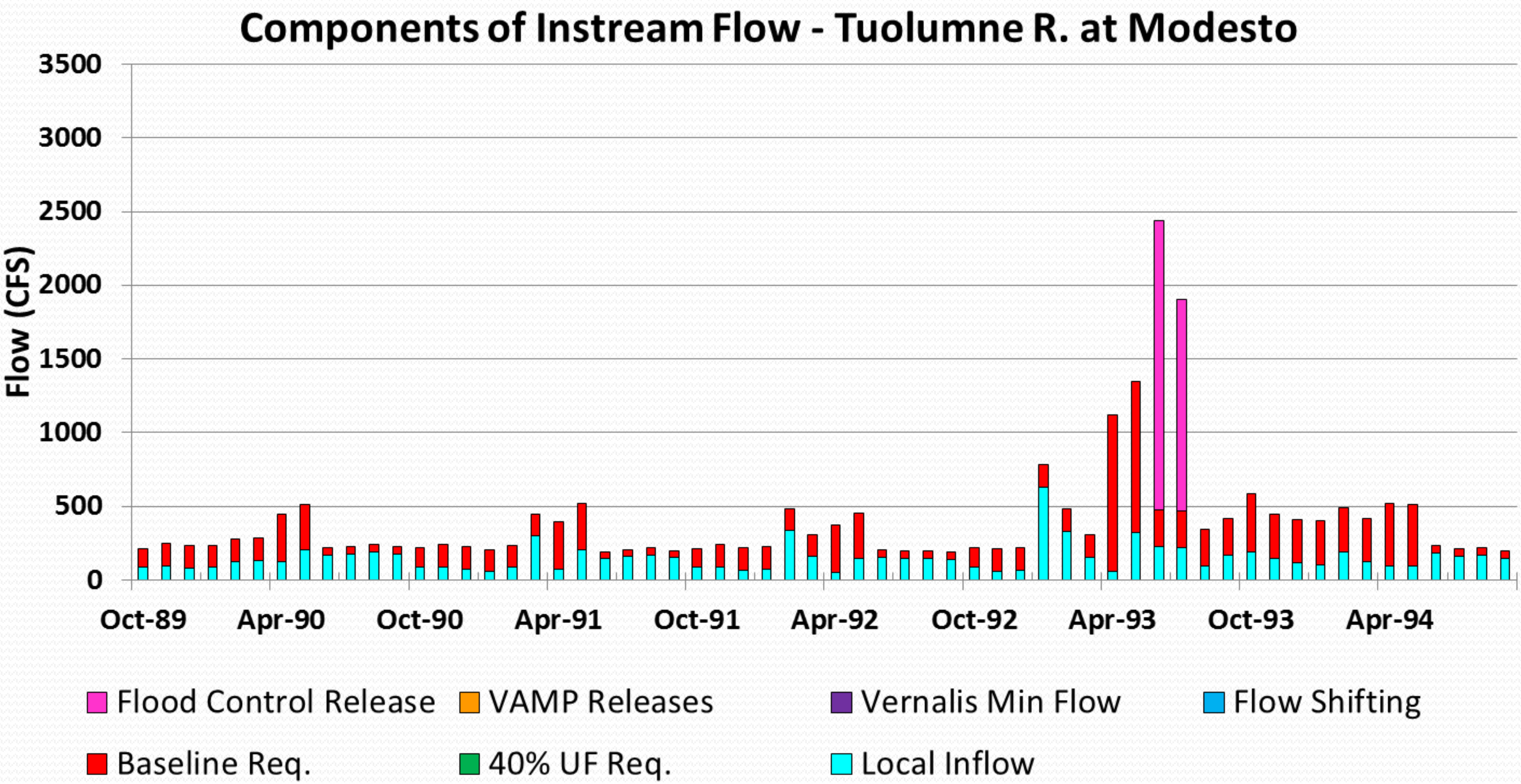
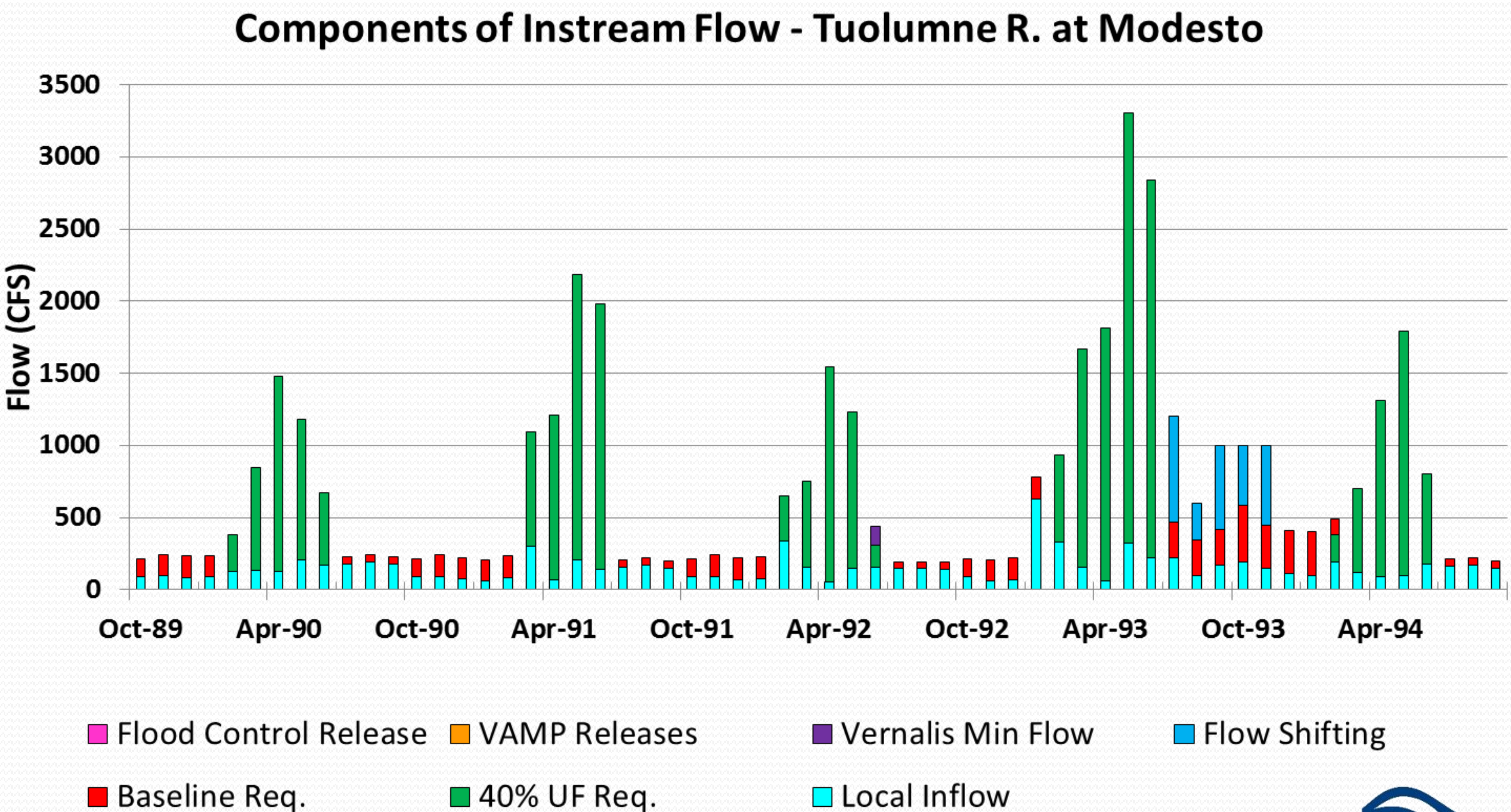
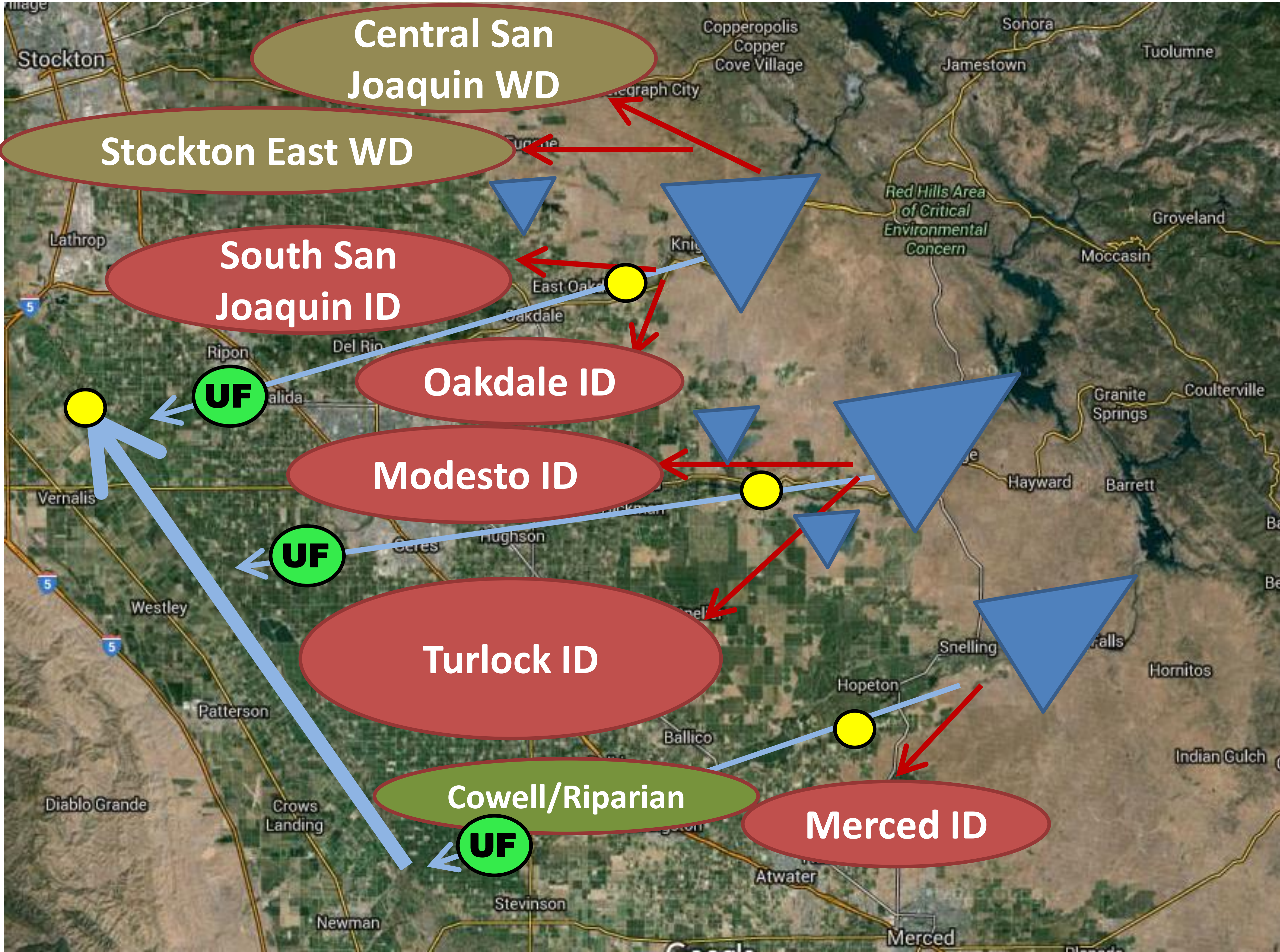
Tuolumne WSE Baseline Flows (1990-1995)



Tuolumne WSE 40% Alt. Flows (1990-1995)

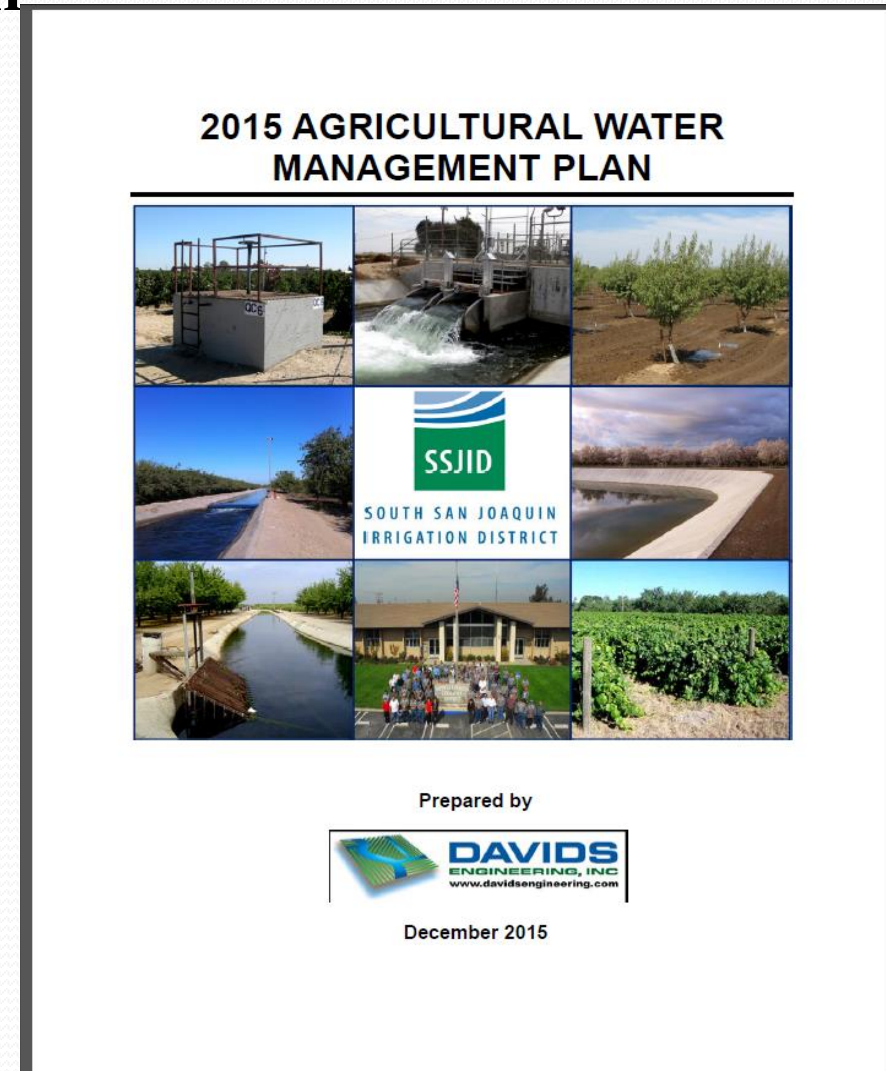


Irrigation District Diversion Demand Characterization


Central San Joaquin WD
Stockton East WD
South San Joaquin ID
Oakdale ID
Modesto ID
Turlock ID
Cowell/Riparian
Merced ID
UF
UF
UF
Stockton
Lathrop
Ripon
Del Rio
Oakdale
Vernalis
Westley
Patterson
Diablo Grande
Crows Landing
Newman
Stevinson
Atwater
Merced
Ballico
Hopeton
Snelling
Hughson
Ceres
Copperopolis
Copper Cove Village
Sonora
Jamestown
Tuolumne
Red Hills Area of Critical Environmental Concern
Groveland
Moccasin
Granite Springs
Coulterville
Hayward
Barrett
Hornitos
Indian Gulch

Agricultural Water Use Data Sources

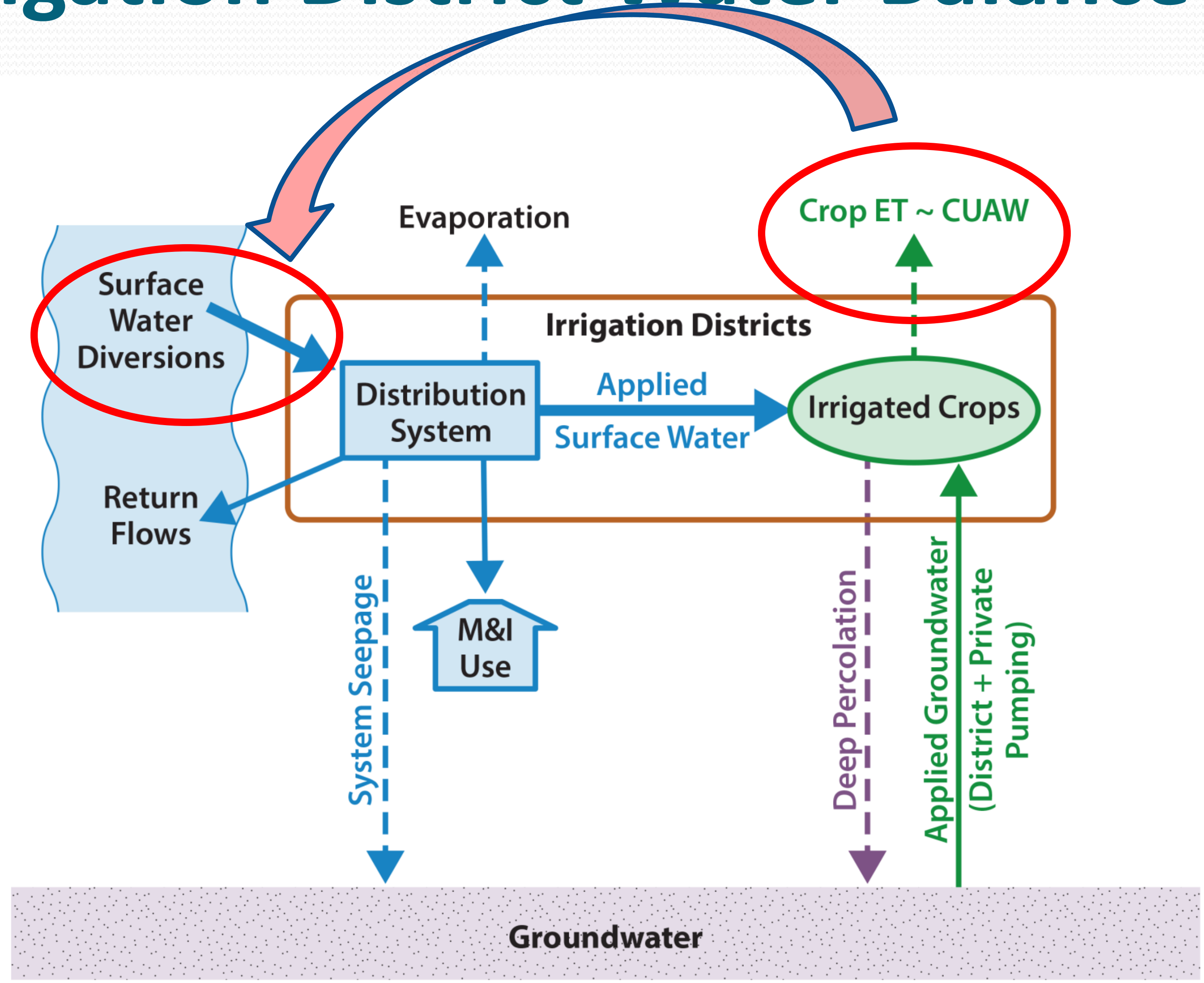
- **Demand parameters based on District AWMPs**
  - Total Diversion
  - Municipal deliveries
  - Seepage from regulating reservoirs
  - Minimum annual groundwater pumping
  - Maximum Groundwater Pumping Capacity
  - Distribution losses
  - Deep percolation fraction


2015 AGRICULTURAL WATER MANAGEMENT PLAN

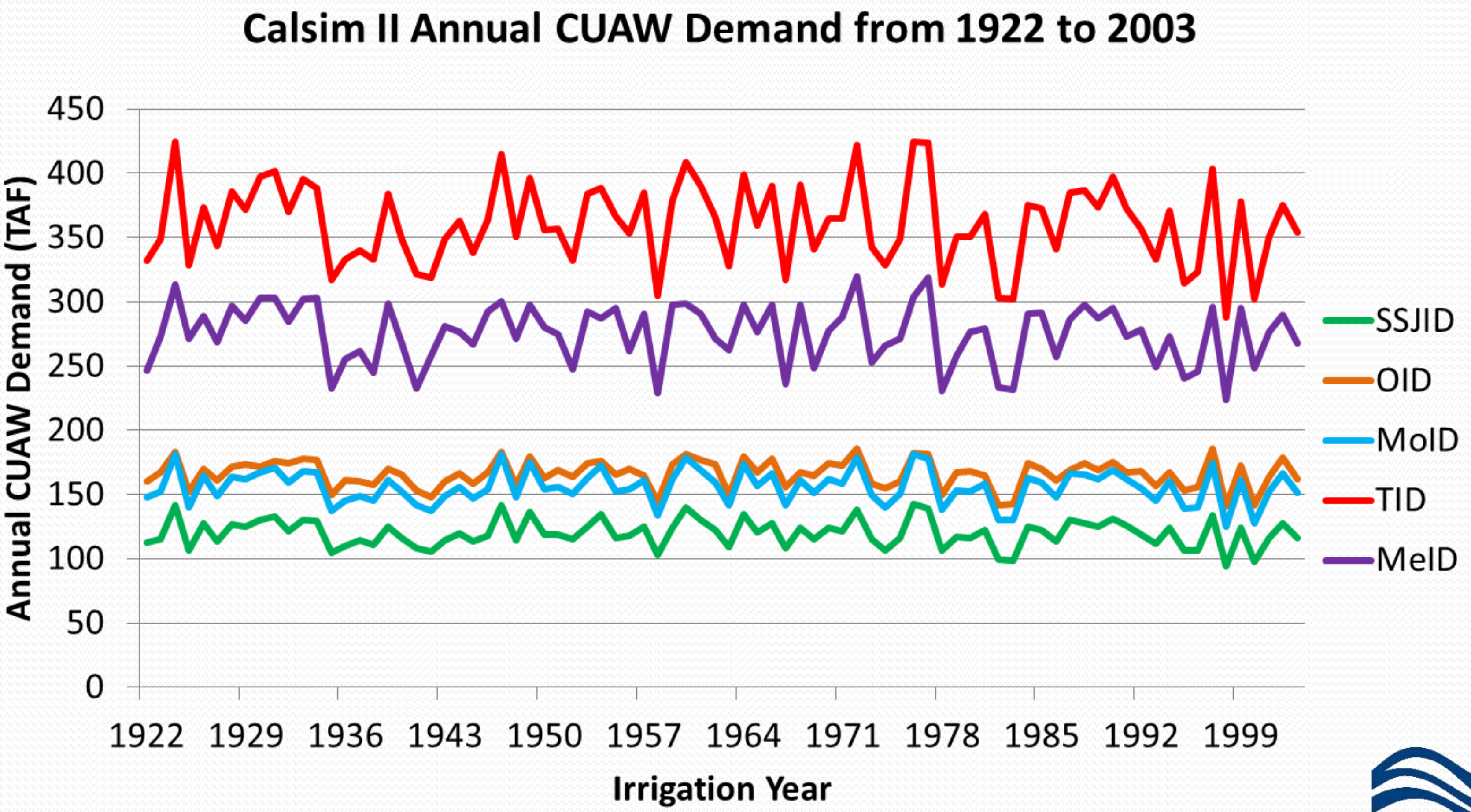
Prepared by

December 2015

Irrigation District Water Balance



CUAW: Consumptive Use of Applied Water



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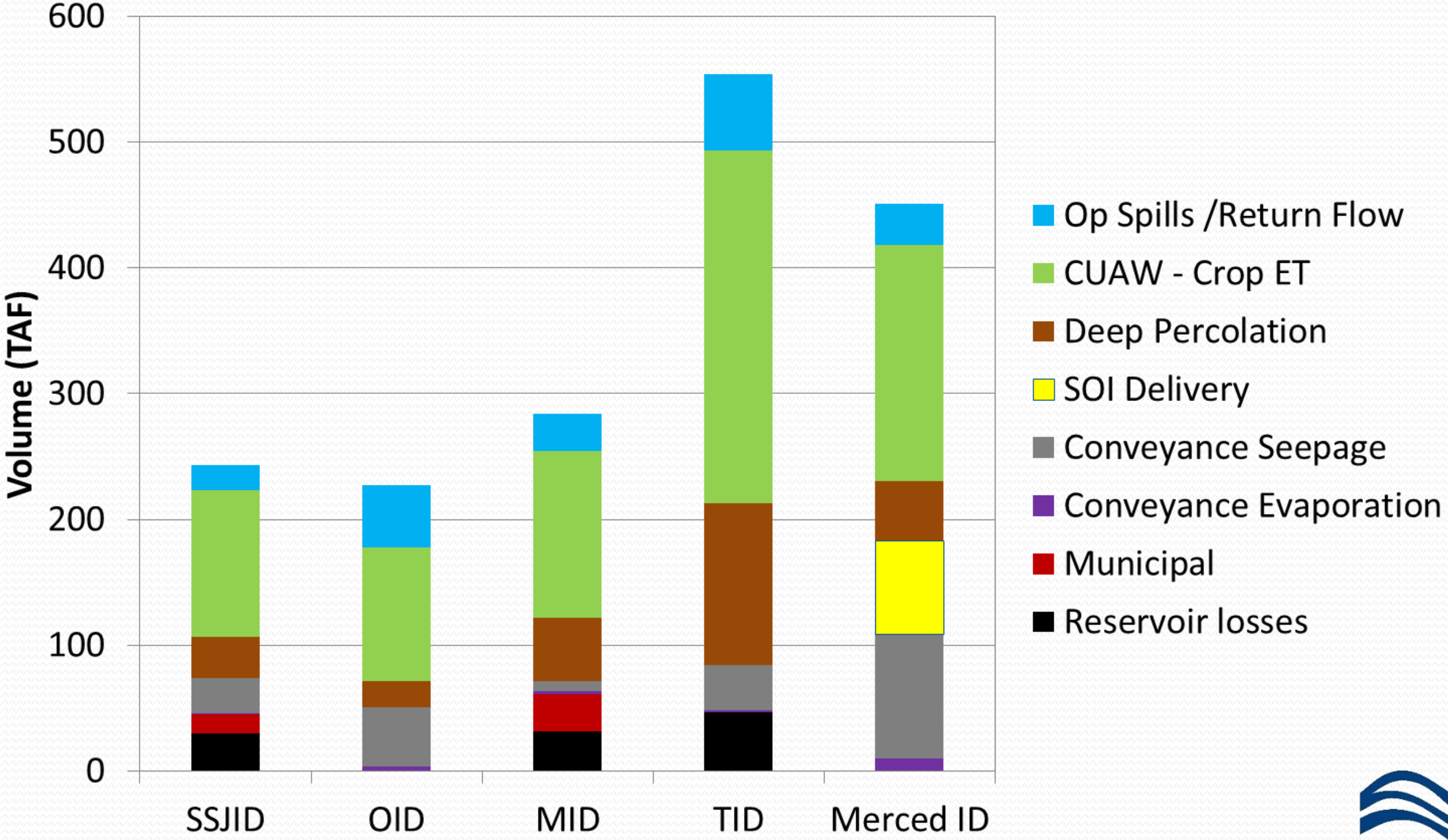
Average Fate of Surface Water Diversions



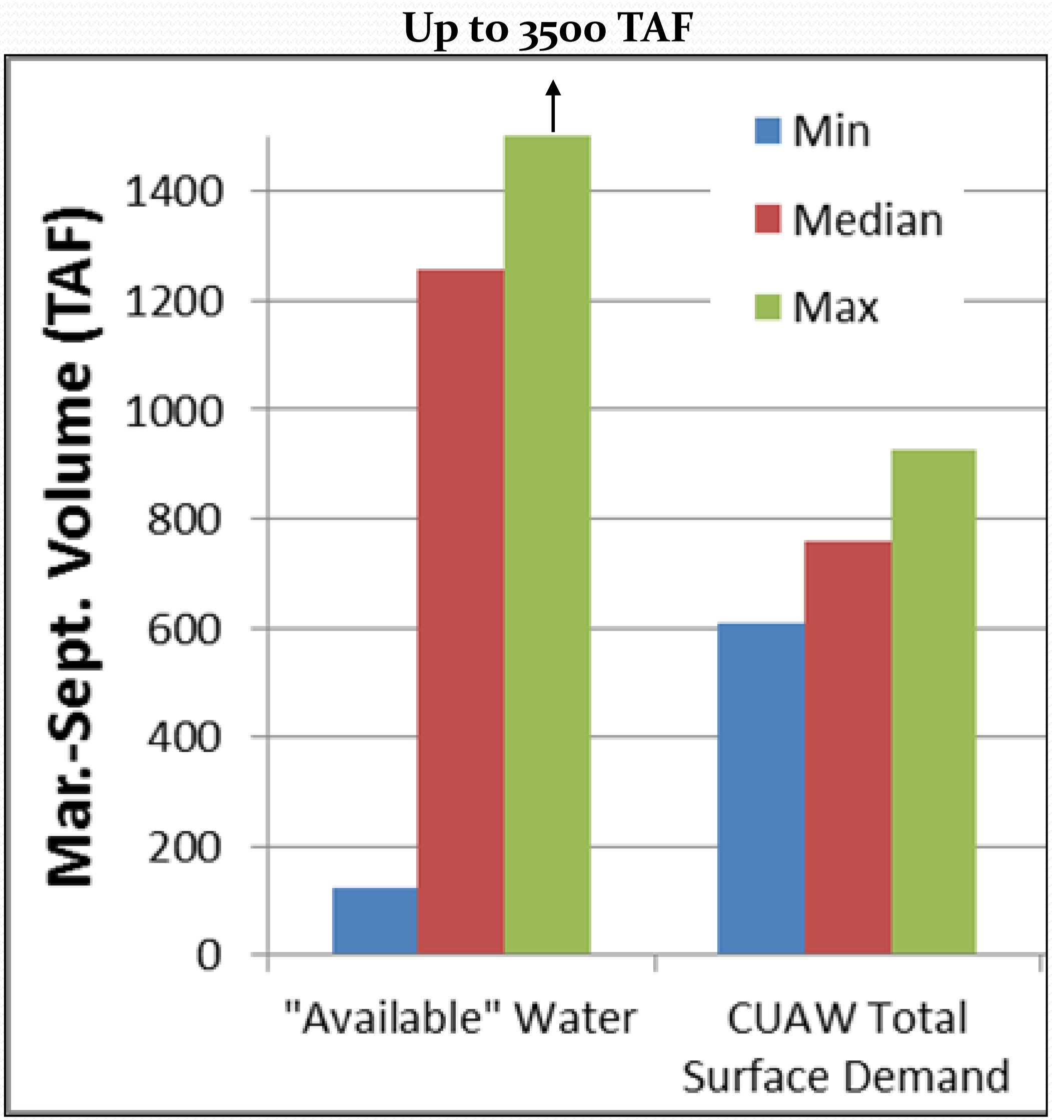
Characterization of District Demands

- CUAW Crop requirements
- Generalized Efficiencies from AWMPs
- Minimum GW pumping from AWMPs/Information request letters
- CUAW demand adjusted 9-15% such that resulting diversions most reasonable match with operations models and historical range, where applicable
- Consistent with AWMP data but fewer years available

Calculation of Annual Allocation: Reservoir Constraints

- End-of-September Carryover Storage Guidelines
- Allowable Draw from Storage
- Minimum Allocation Fraction
- Drought Refill Provision

Tuolumne Supply and Demand



Calculation of Annual Allocation

- Similar to New Melones Index:

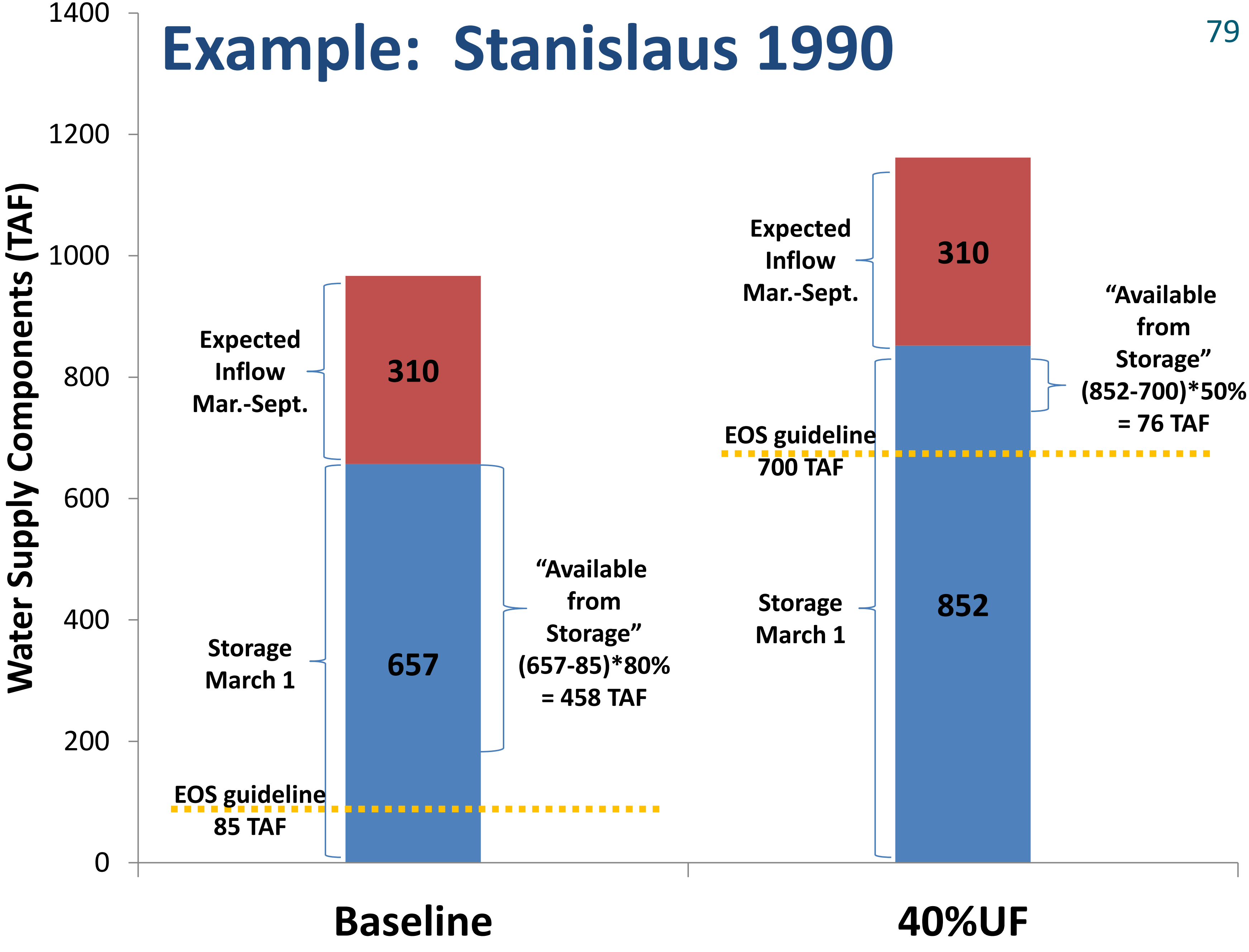
  = [**Storage End-of-Feb.**] + [**Anticipated Inflow Mar-Sept.**]
- Consider reservoir contraints:
  - End-of-Sept. Carryover Guideline
  - Percent Draw from Storage
- Subtract streamflow requirements Mar-Sept
- If sufficient water, district demands are 100% met
- If not enough, district diversions are curtailed

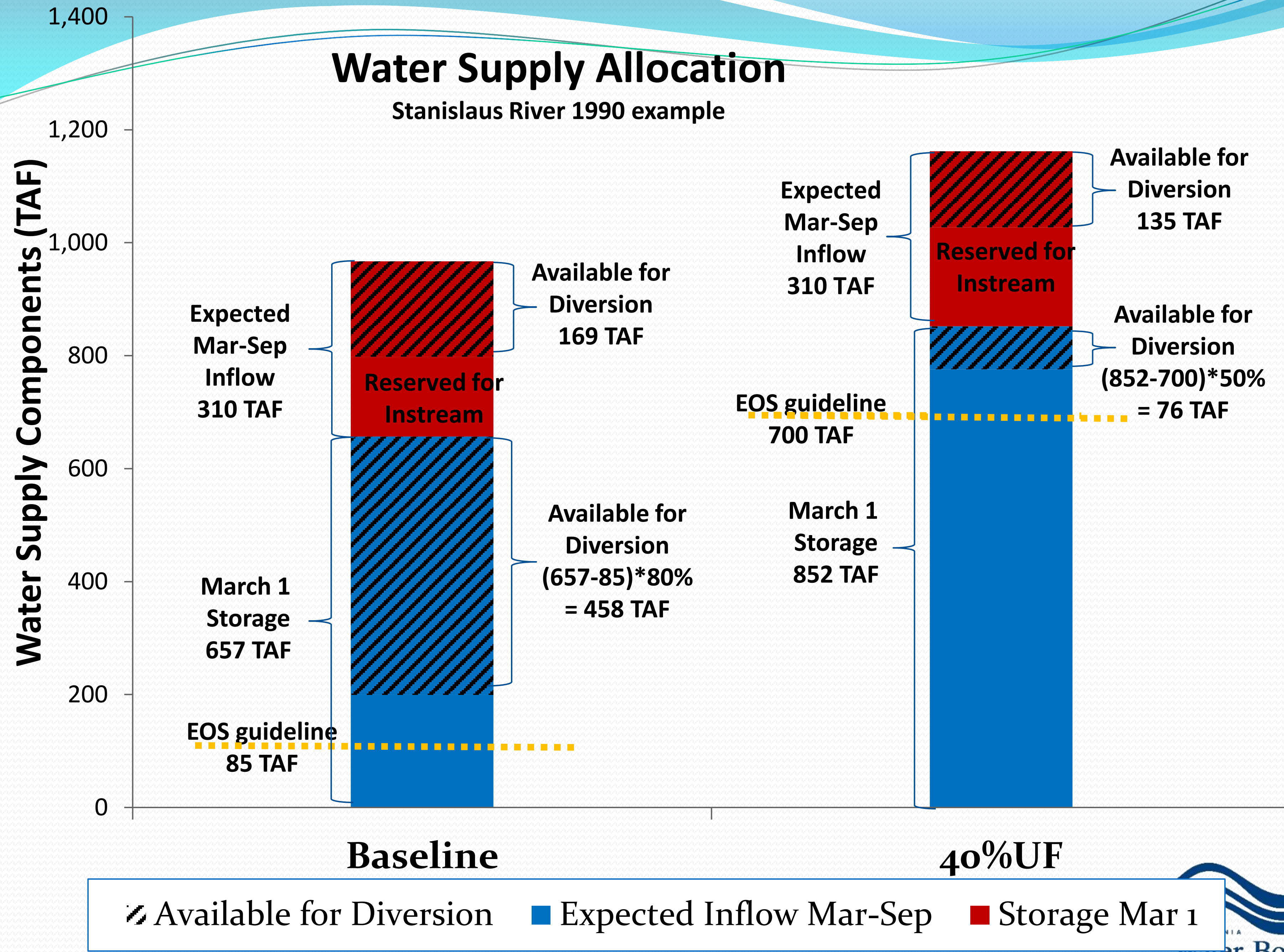
Calculation of Annual Allocation

1. Determine Streamflow Requirement
   - (Feb-June Percent Unimpaired Flow, etc.)
2. Determine "Available Water"
   - from: A. Net inflows (after streamflow requirement);
     B. Storage March 1;
     C. Storage End-of-Sept. Guideline, Percent Draw
3. Determine "Growing Season Demand"
   - (CUAW → Total Surface Demand *March-Sept.*)
4. Determine "Growing Season Allocation"
   - Allocation = %DemandMet = (G.S. Diversion)/(G.S. Demand)

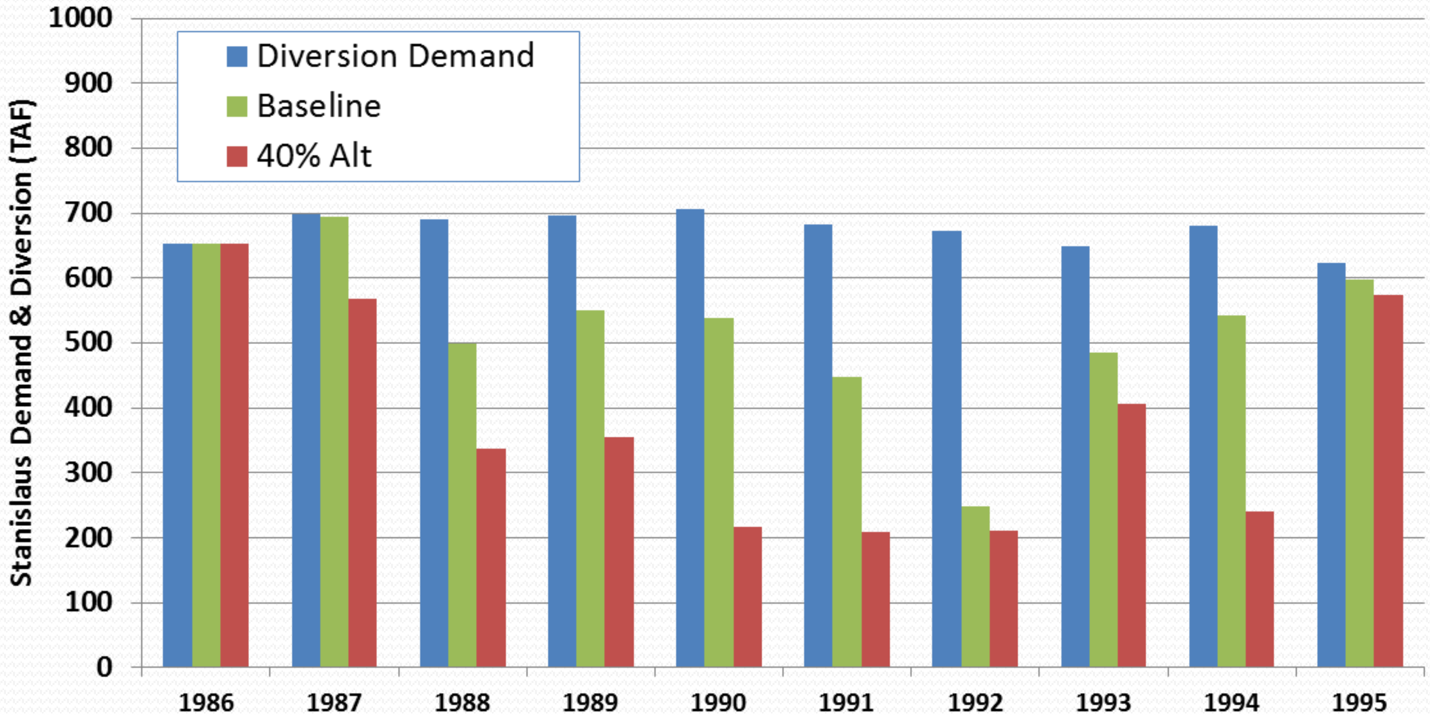
   →also continues Oct.-Feb. until next allocation

Example: Stanislaus 1990



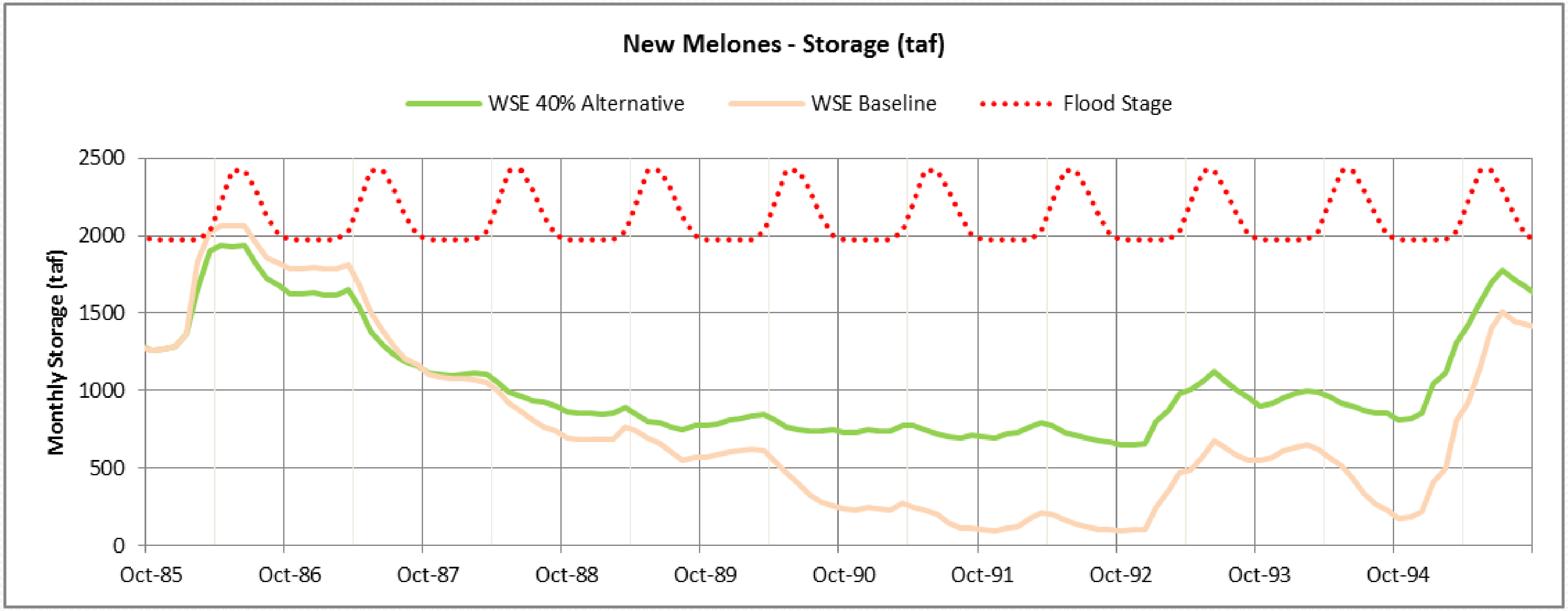

Water Supply Allocation
Stanislaus River 1990 example
Water Supply Components (TAF)
1,400
1,200
1,000
800
600
400
200
0
Expected Mar-Sep Inflow 310 TAF
Available for Diversion 169 TAF
Reserved for Instream
March 1 Storage 657 TAF
Available for Diversion (657-85)*80% = 458 TAF
EOS guideline 85 TAF
Expected Mar-Sep Inflow 310 TAF
Available for Diversion 135 TAF
Reserved for Instream
Available for Diversion (852-700)*50% = 76 TAF
EOS guideline 700 TAF
March 1 Storage 852 TAF
Baseline
40%UF
Available for Diversion
Expected Inflow Mar-Sep
Storage Mar 1

Stanislaus Total Annual District Diversion 1986 to 1995



Alternative	Averages over 1986 to 1995			
	Diversion Demand	Diversion	Diversion Shortage	Percent of Demand Met
	TAF	TAF	TAF	%
Baseline	676	526	150	78%
40% Alt	676	377	299	56%

Stanislaus Reservoir Storage Condition 1986 to 1995



Possible Exceptions within Allocation Framework

- Minimum district diversion (during dry conditions)
- End-of-drought refill (during wet conditions after dry)
- Existing agreements (e.g., 1988 Agreement)
- Vernalis EC and flow requirements may increase volume of water needed for instream use

Table F.1.2-23a. Minimum Diversion, Minimum September Carryover Guideline, Maximum Draw from Storage, and Flow Shifting for the Stanislaus River

	Baseline	20% Unimpaired Flow	30% Unimpaired Flow	40% Unimpaired Flow	50% Unimpaired Flow	60% Unimpaired Flow
Minimum District Diversion (TAF, % of District Max)	0 TAF	210 TAF (35%)	210 TAF (35%)	210 TAF (35%)	180 TAF (30%)	180 TAF (30%)
Minimum September Carryover Guideline (TAF)	85	700	700	700	700	700
Maximum Storage Draw (% of Mar 1 minus Sep guideline)	80%	80%	70%	50%	45%	35%
Flow Shifting to Fall[a]	NA	None	None	Yes	Yes	Yes
End-of-Drought Storage Refill	NA	100%	100%	70%	50%	50%
Vernalis Minimum[b] Feb–Jun (cfs)	D-1641/ VAMP	1,000	1,000	1,000	1,000	1,000

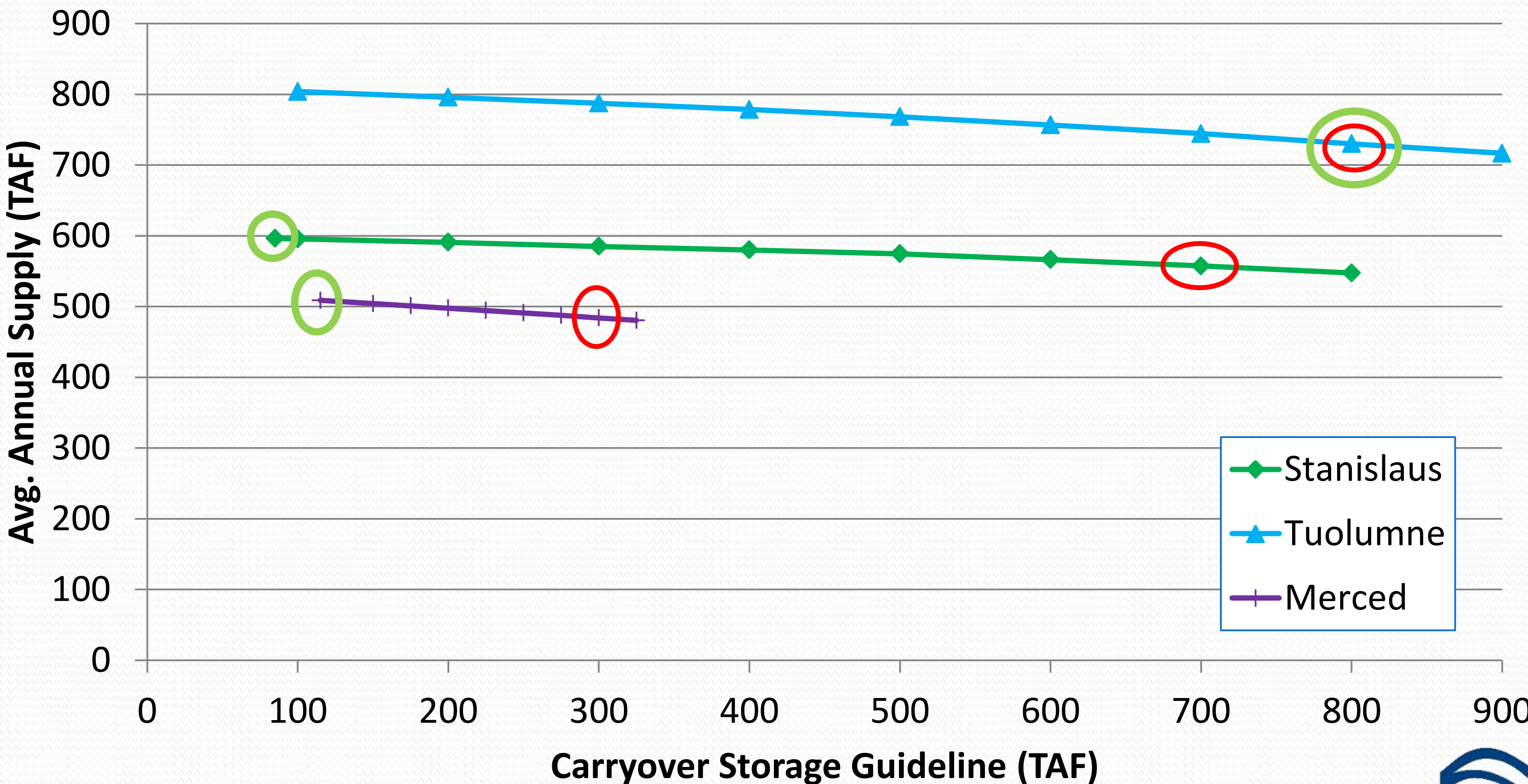
Table F.1.2-23b. Minimum Diversion, Minimum September Carryover Guideline, Maximum Draw from Storage, and Flow Shifting for the Tuolumne River

	Baseline	20% Unimpaired Flow	30% Unimpaired Flow	40% Unimpaired Flow	50% Unimpaired Flow	60% Unimpaired Flow
Minimum District Diversion (TAF, % of District Max)	550 TAF (50%)	363 TAF (33%)	363 TAF (33%)	363 TAF (33%)	275 TAF (20%)	275 TAF (20%)
Minimum September Carryover Guideline (TAF)	800	800	800	800	800	800
Maximum Storage Draw (% of Mar 1 minus Sep guideline)	65%	60%	55%	50%	45%	35%
Flow Shifting to Fall[a]	NA	None	None	Yes	Yes	Yes
Drought End Storage Refill	NA	100%	100%	70%	50%	50%
Vernalis Minimum[b] Feb–Jun (cfs)	D-1641/ VAMP	1,000	1,000	1,000	1,000	1,000

Table F.1.2-23c. Minimum Diversion, Minimum September Carryover Guideline, Maximum Draw from Storage, and Flow Shifting for the Merced River

	Baseline	20% Unimpaired Flow	30% Unimpaired Flow	40% Unimpaired Flow	50% Unimpaired Flow	60% Unimpaired Flow
Minimum District Diversion (TAF, % of District Max)	0 TAF	78 TAF (15%)	78 TAF (15%)	78 TAF (15%)	78 TAF (15%)	78 TAF (15%)
Minimum September Carryover Guideline (TAF)	115 TAF	300	300	300	300	300
Maximum Storage Draw (% of Mar 1 minus Sep guideline)	80%	70%	60%	50%	45%	35%
Shifting to Fall[a]	NA	None	None	Yes	Yes	Yes
Drought End Storage Refill	NA	100%	100%	100%	50%	50%
Vernalis Minimum[b] Feb–Jun (cfs)	D-1641/ VAMP	1000	1000	1000	1000	1000

Sensitivity to Carryover Storage: Avg. Annual Supply; 40% UF Objective



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Flow Shifting: Generalized Concept

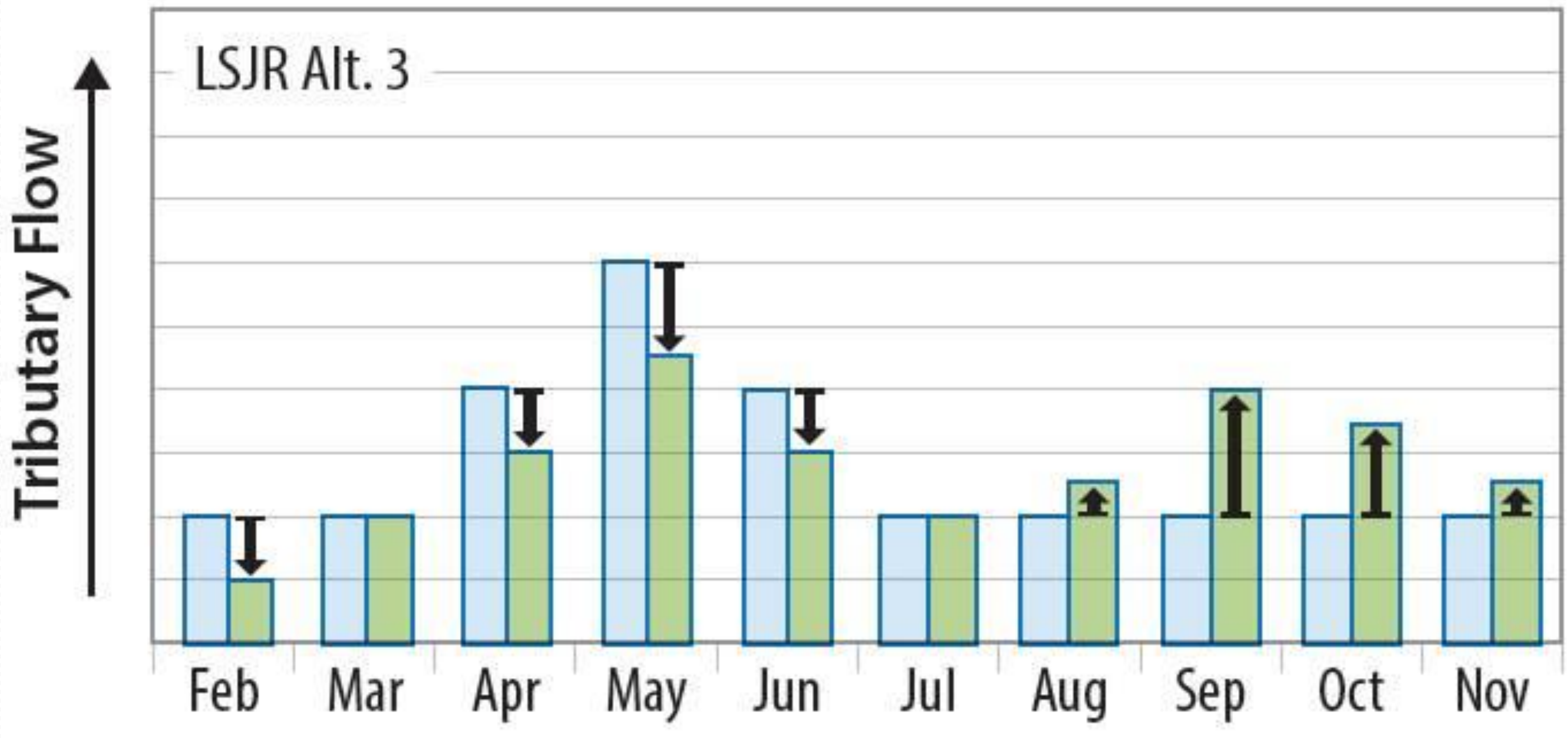

Figure F.1.2-7. Generalized Illustration of Shifting of Flow Requirement to Summer and Fall

Flow Shifting: Flow targets

Table F.1.2-25. Instream Flow Targets July–November that Determine Necessary Volume of Flow Shifting from the February–June Period

A. Stanislaus Minimum Flow by Water Year Type and Month					
WYT	July (cfs)	August (cfs)	September (cfs)	October (cfs)	November (cfs)
W	800	500	800	1,400	—
AN	—	—	—	1,200	—
BN	—	—	—	1,000	—
D	—	—	—	1,000	—
C	—	—	—	1,000	—
B. Tuolumne Minimum Flow by Water Year Type and Month					
WYT	July (cfs)	August (cfs)	September (cfs)	October (cfs)	November (cfs)
W	1,200	600	1,000	1,000	1,000
AN	—	—	—	—	—
BN	—	—	—	—	—
D	—	—	—	—	—
C	—	—	—	—	—
C. Merced Minimum Flow by Water Year Type and Month					
WYT	July (cfs)	August (cfs)	September (cfs)	October (cfs)	November (cfs)
W	600	600	600	800	800
AN	200	200	200	—	—
BN	—	—	—	—	—
C	—	—	—	—	—
D	—	—	—	—	—

Flow Shifting: Resultant Shifted Volumes

Table F.1.2-26. Average Quantity of Flow Shifted to Fall for Each Water Year Type

Water Year Type	Stanislaus Annual Flow Shifting (TAF)			Tuolumne Annual Flow Shifting (TAF)			Merced Annual Flow Shifting (TAF)		
	40% alt	50% alt	60% alt	40% alt	50% alt	60% alt	40% alt	50% alt	60% alt
W	51	51	52	102	102	102	105	116	120
AN	17	17	18	0	0	0	11	11	11
BN	8	9	9	0	0	0	0	0	0
D	10	11	13	0	0	0	0	0	0
C	4	5	5	0	0	0	0	0	0
Average	21	22	23	29	29	29	32	35	36

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End of Part 1: Questions

Staff Technical Workshop Part 2:
Water Supply Effects (WSE) Model Results

Analytical Tools Used to Develop the Amendment to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary and Supporting Revised Substitute Environmental Document (SED)

December 5, 2016

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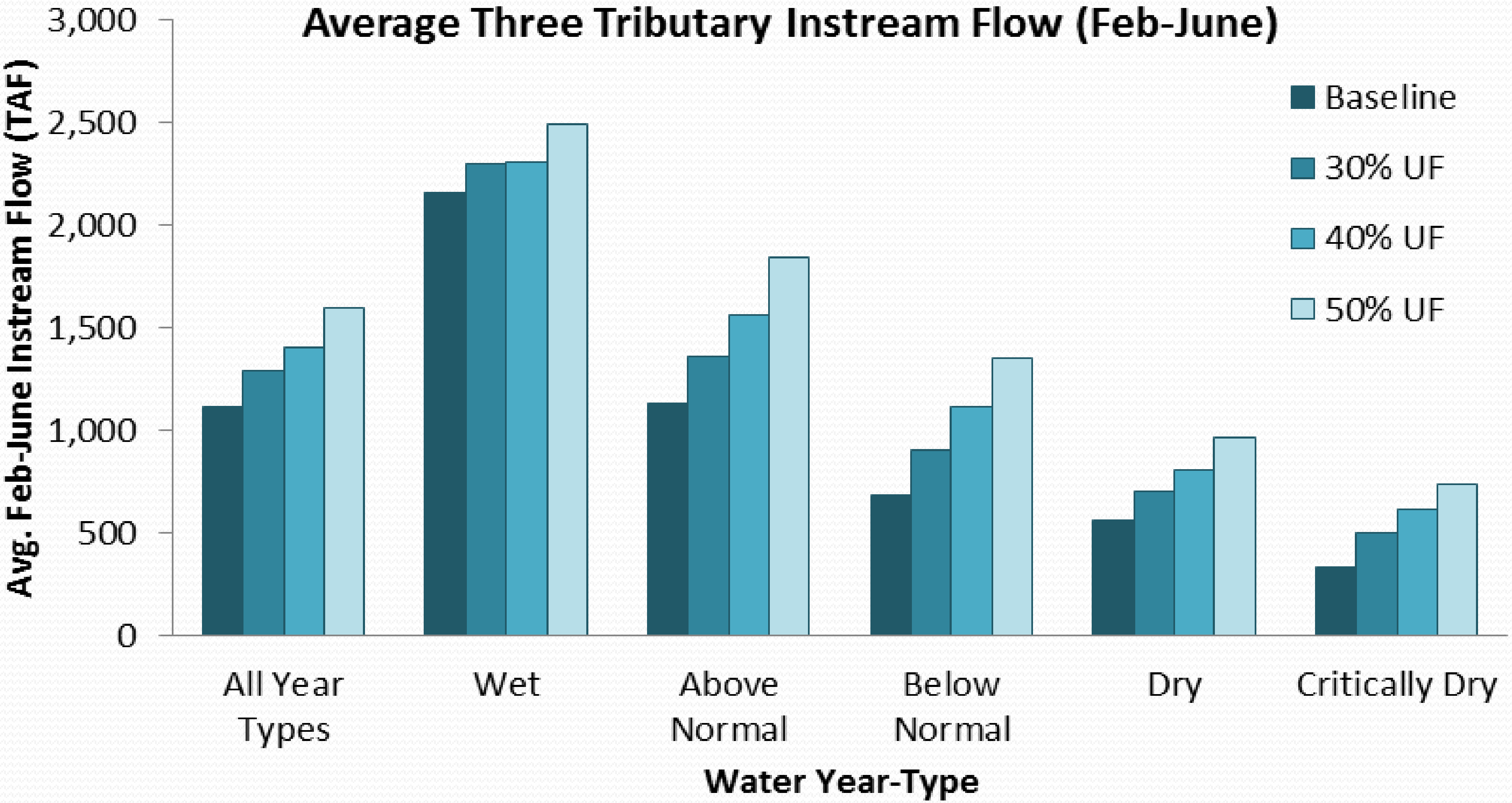
Proposed Flow Increases. . .



Under the 40% unimpaired flow (UF) proposal, average annual instream flow Feb - June would increase by 288 thousand acre feet (TAF), or 26 percent.

Estimated Effect on Average Annual Surface Water Diversion

	Stanislaus (TAF)/(%)	Tuolumne (TAF)/(%)	Merced (TAF)/(%)	Total (TAF)/(%)
Baseline	637/100	851/100	580/100	2,068/100
30% UF Objective	-33/-5	-56/-7	-60/-10	-149/-7
40% UF Objective	-79/-12	-119 /-14	-95/-16	**-293/-14**
50% UF Objective	-136 / -21	-193/-23	-136/ -23	-465/-23

TAF = thousand acre-feet per year

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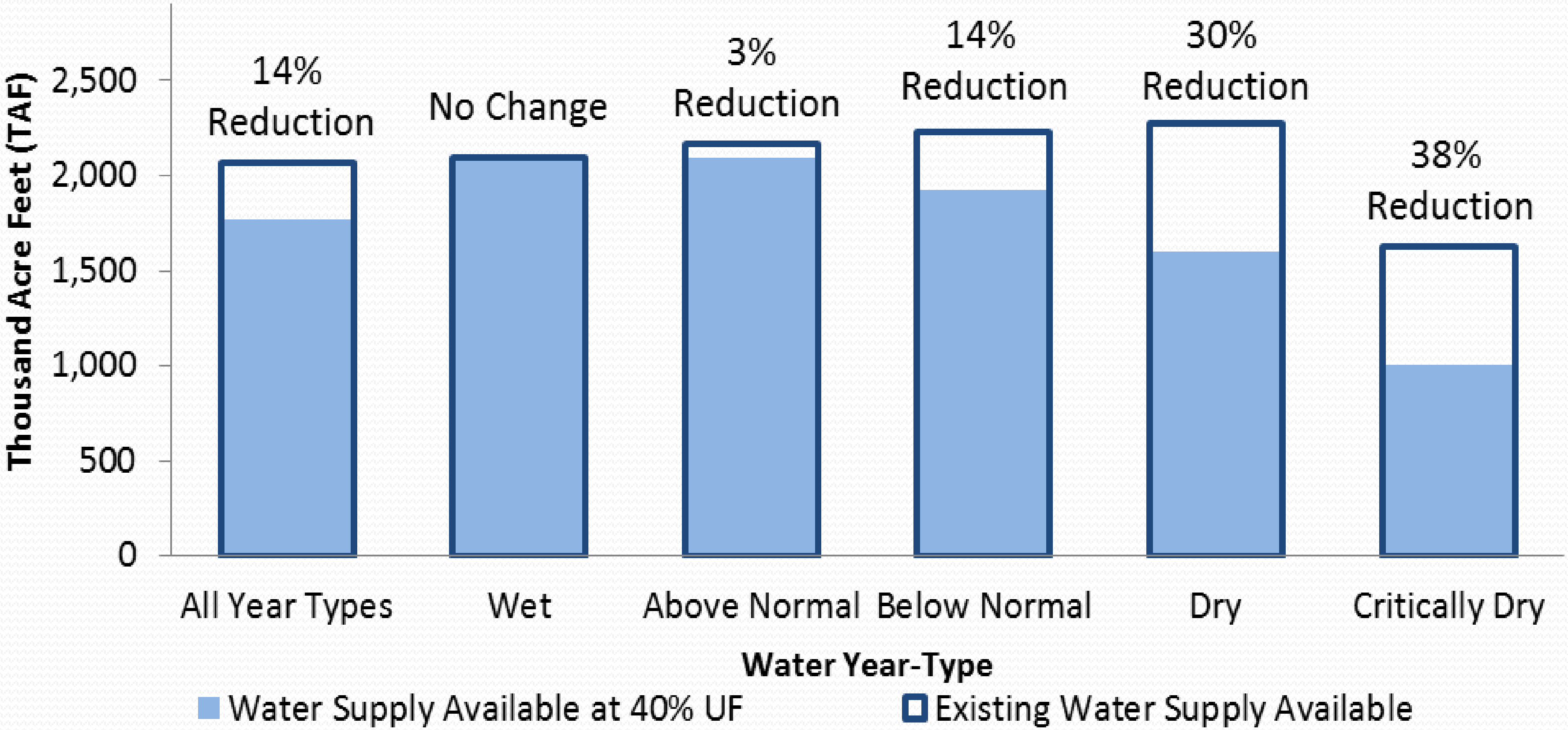
Reduction in Surface Water Availability by Water Year Type (40% UF)



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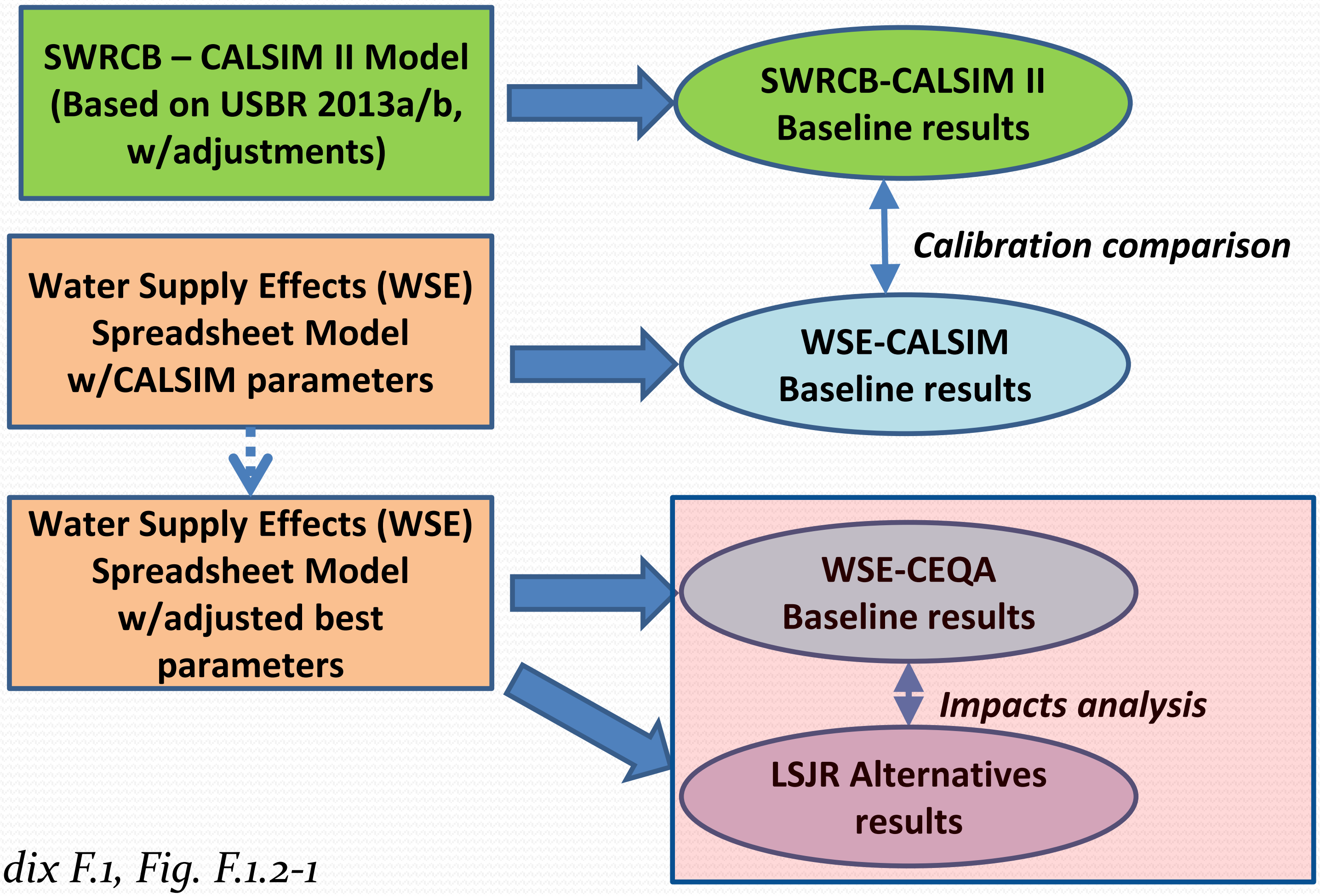
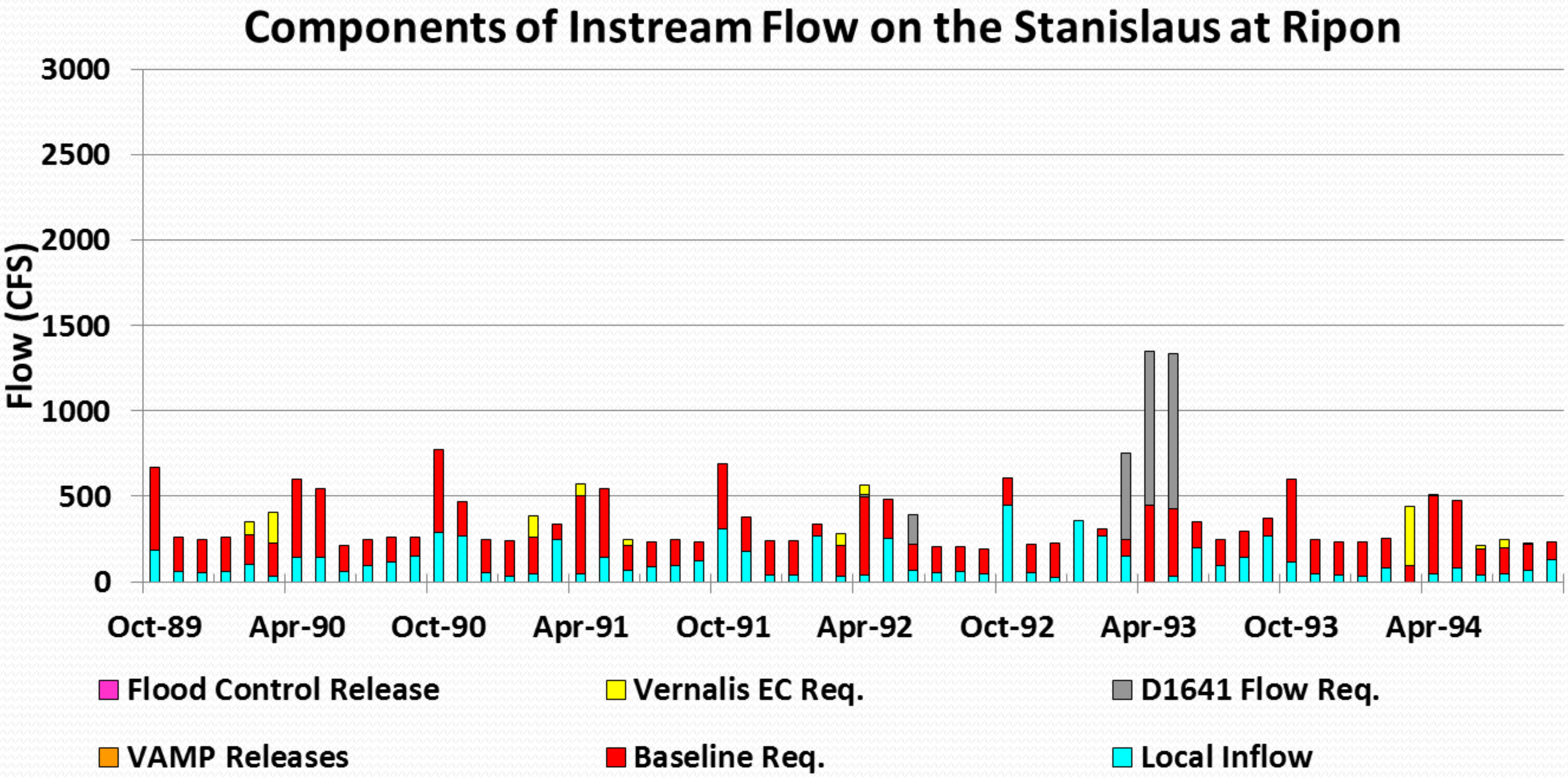
Model comparisons & scenarios



Appendix F.1, Fig. F.1.2-1

Stanislaus WSE Baseline Flows (1990-1995)



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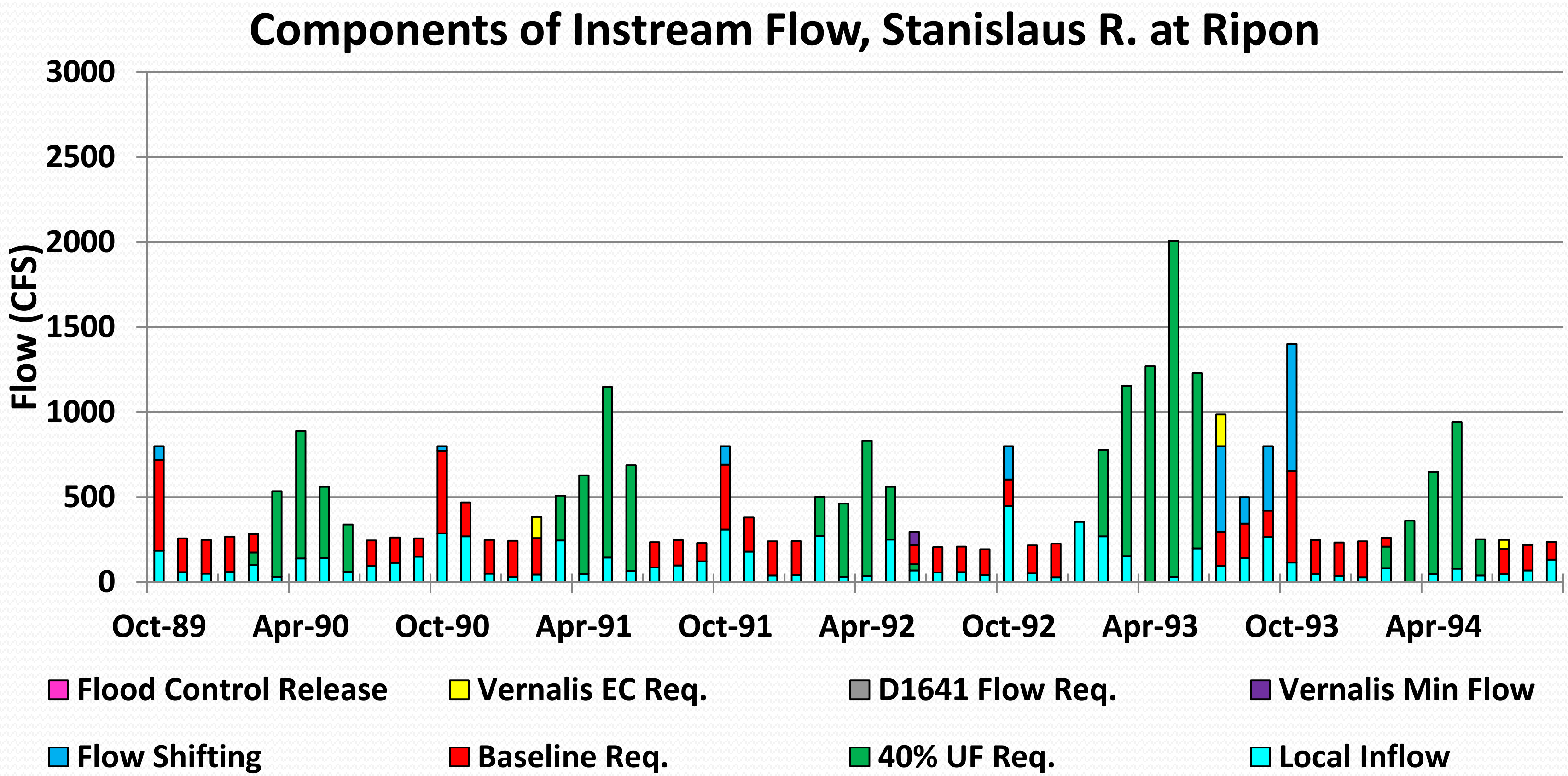
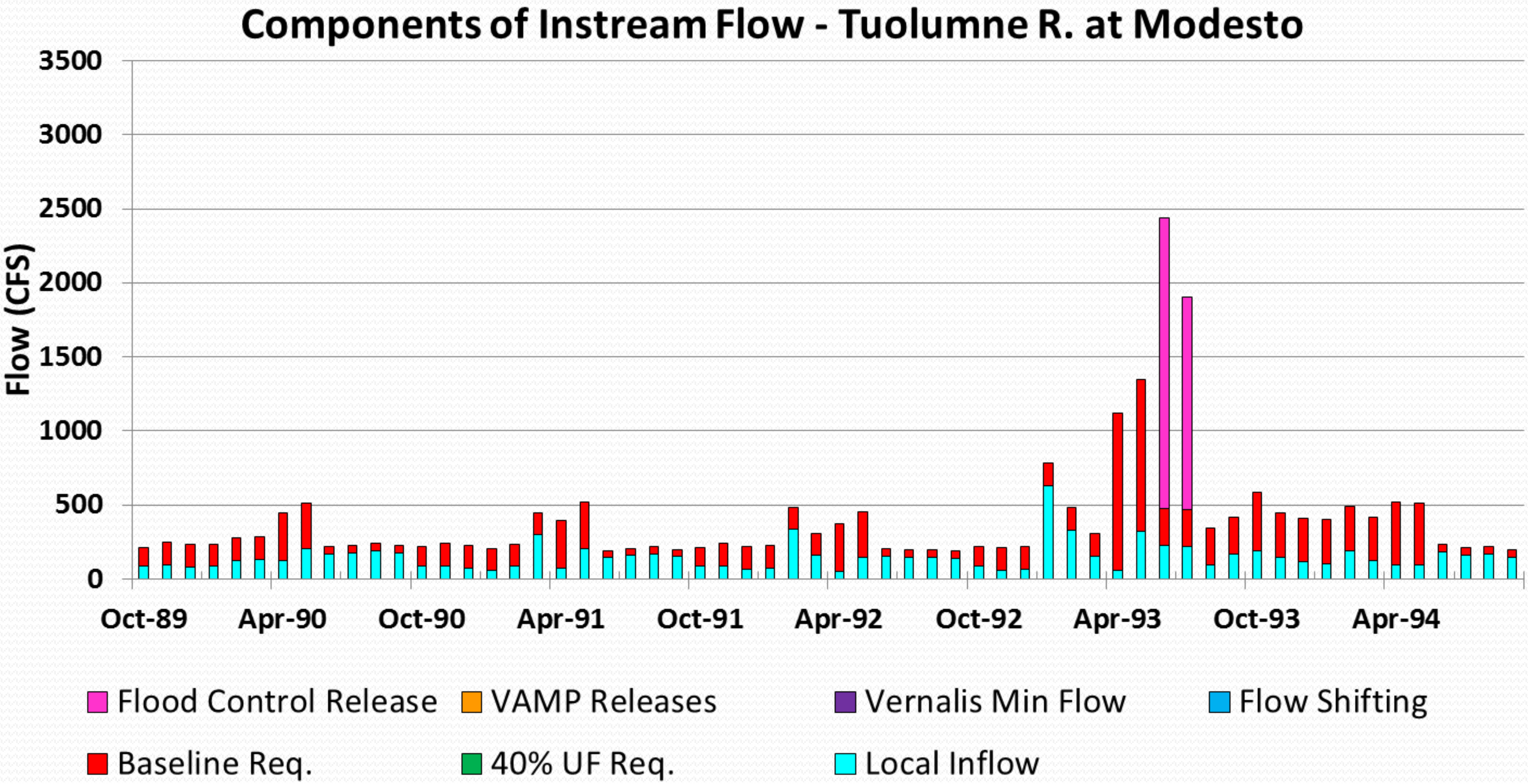
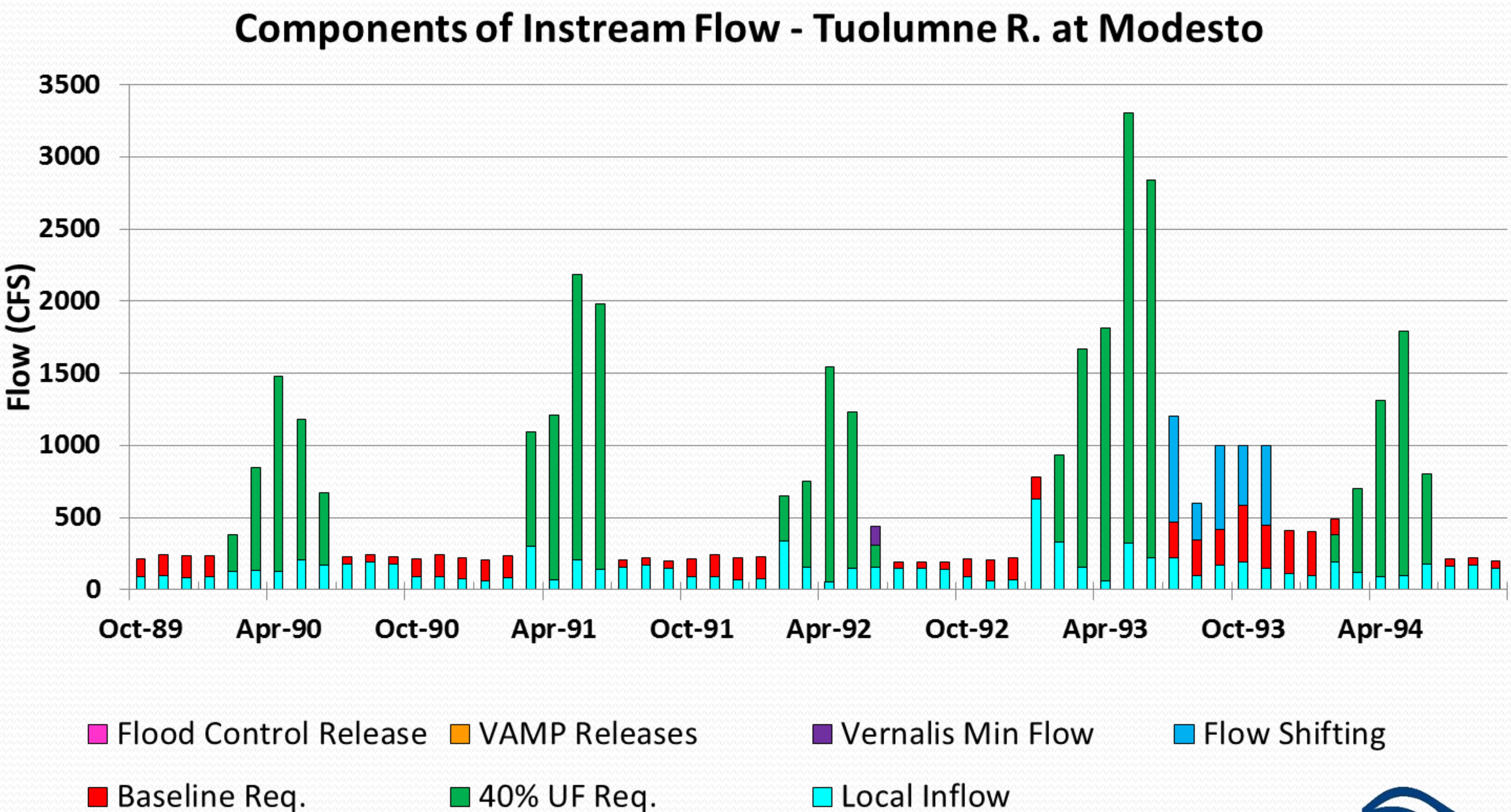
Stanislaus WSE 40% Alt. Flows (1990-1995)



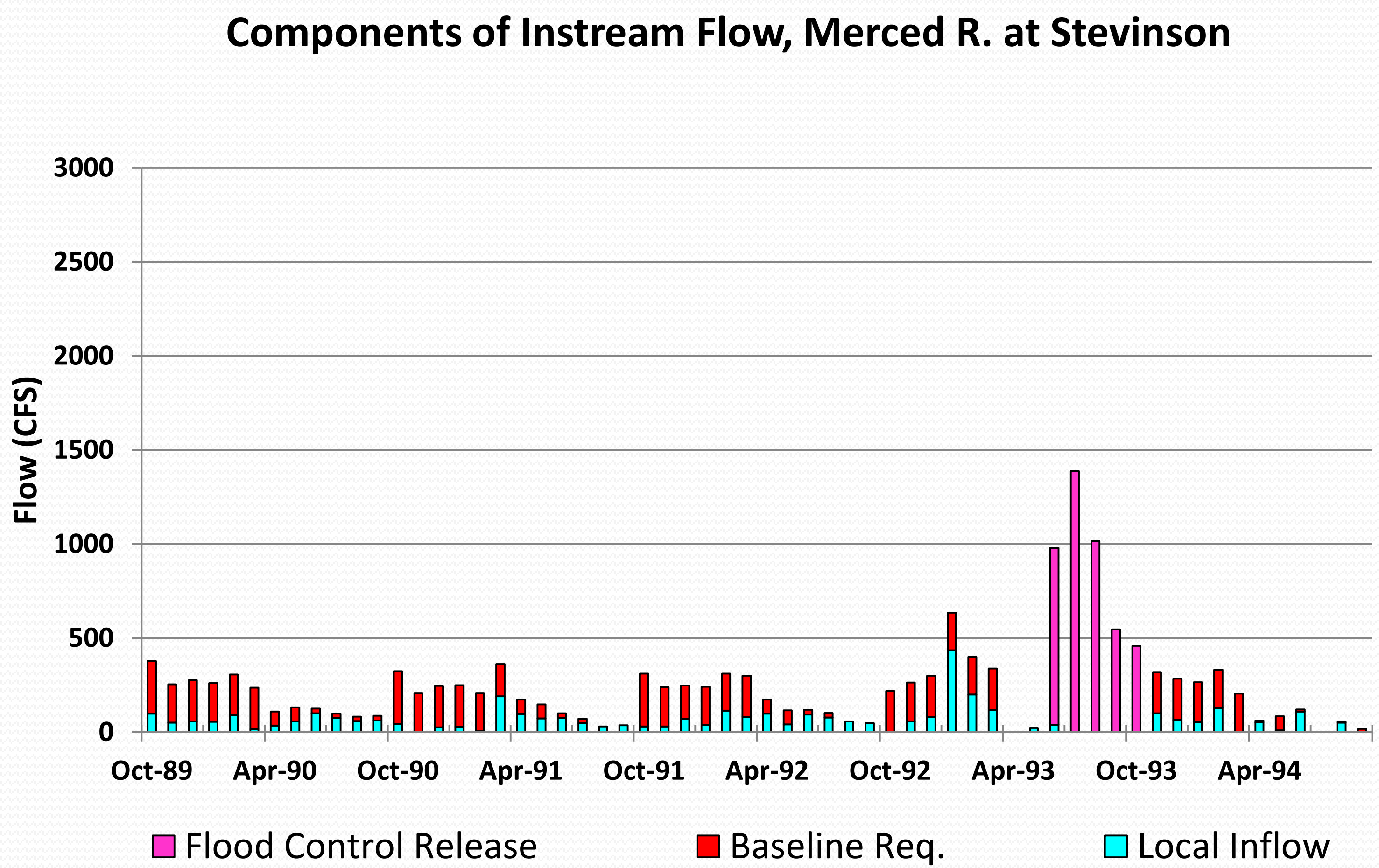
Tuolumne WSE Baseline Flows (1990-1995)



Tuolumne WSE 40% Alt. Flows (1990-1995)



Merced WSE Baseline Flows (1990-1995)



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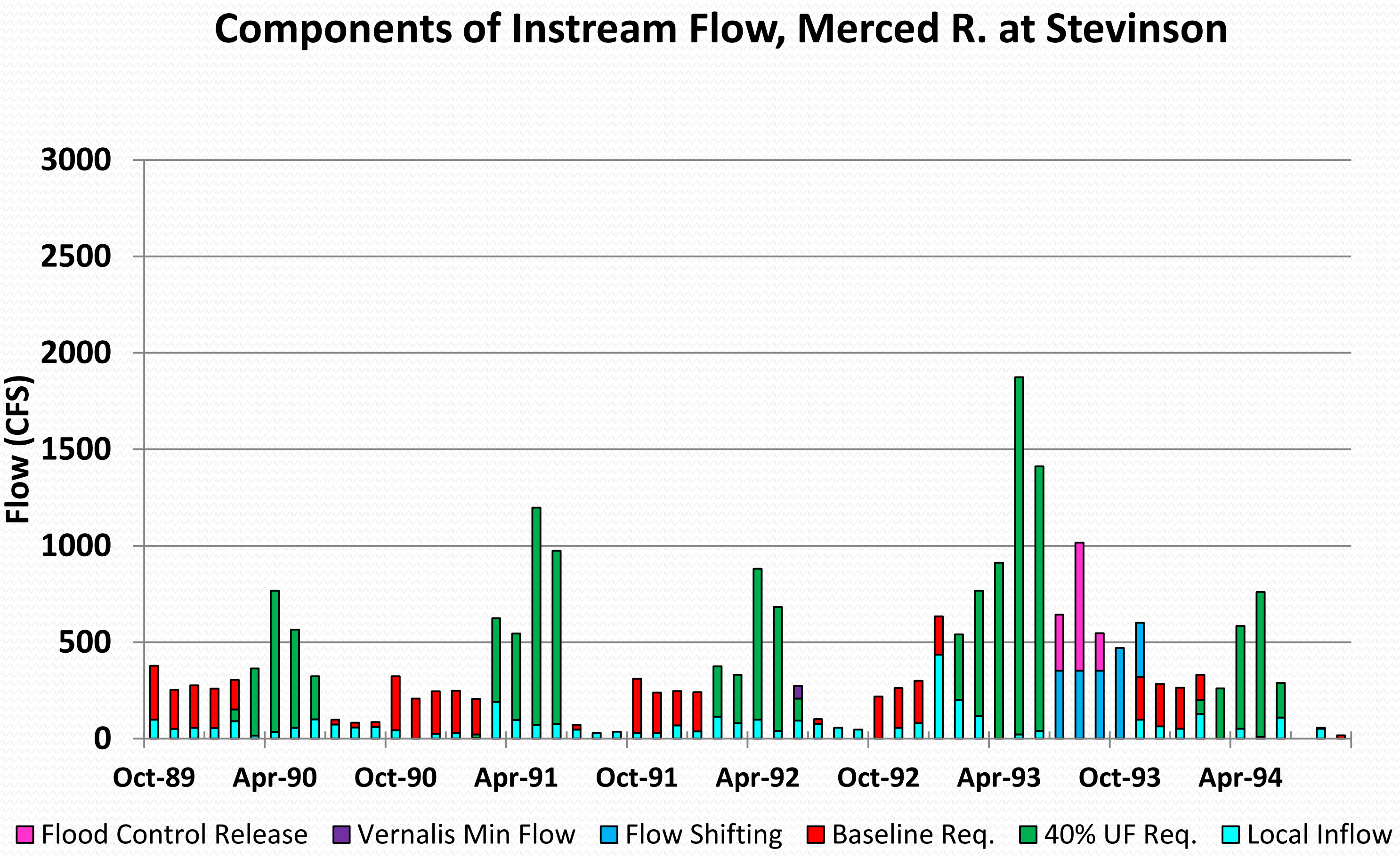
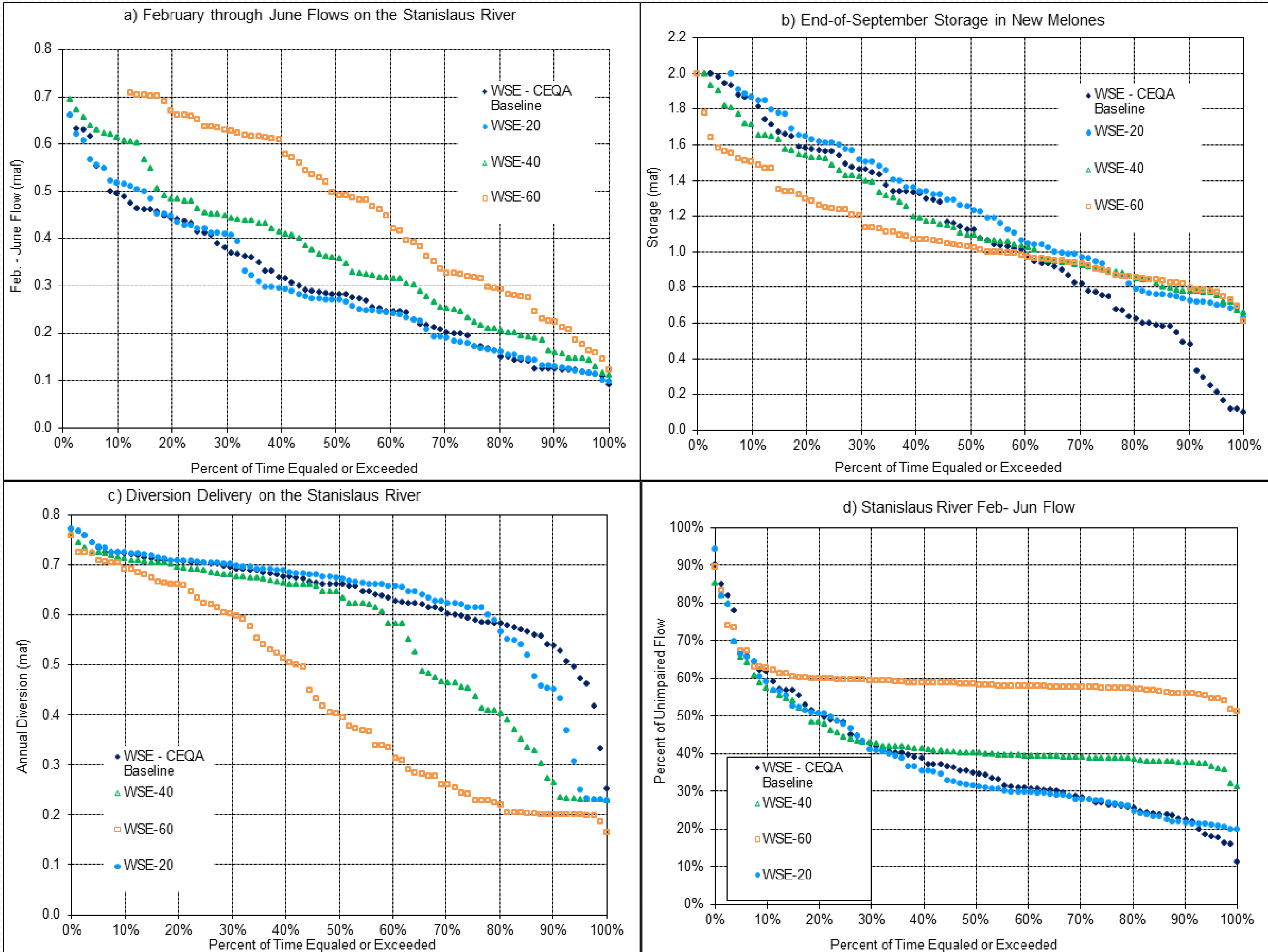
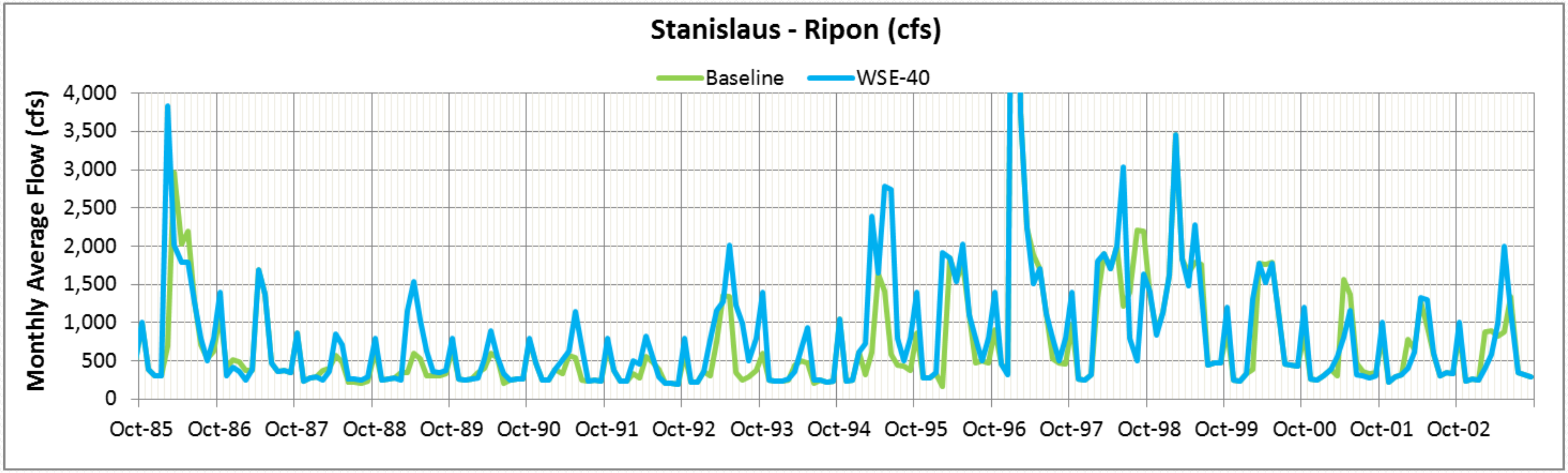
Merced WSE 40% Alt. Flows (1990-1995)



Alternatives Results: Stanislaus River



Stanislaus River at Ripon Instream Flow, WY 1986-2003



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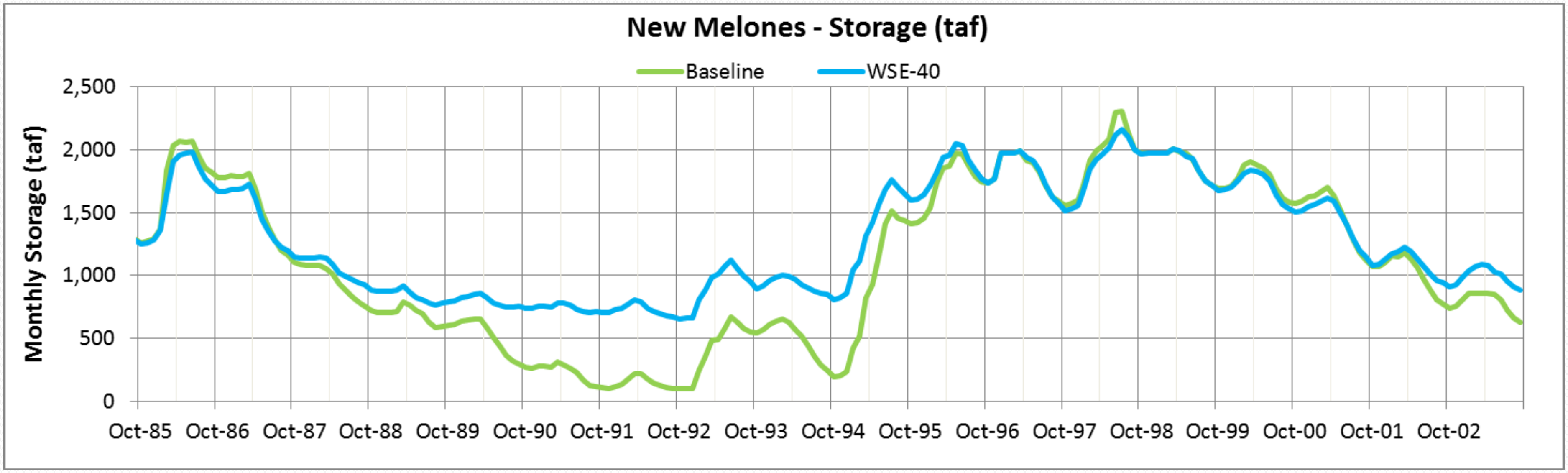
Stanislaus River, New Melones Res. Storage Conditions, WY 1986-2003



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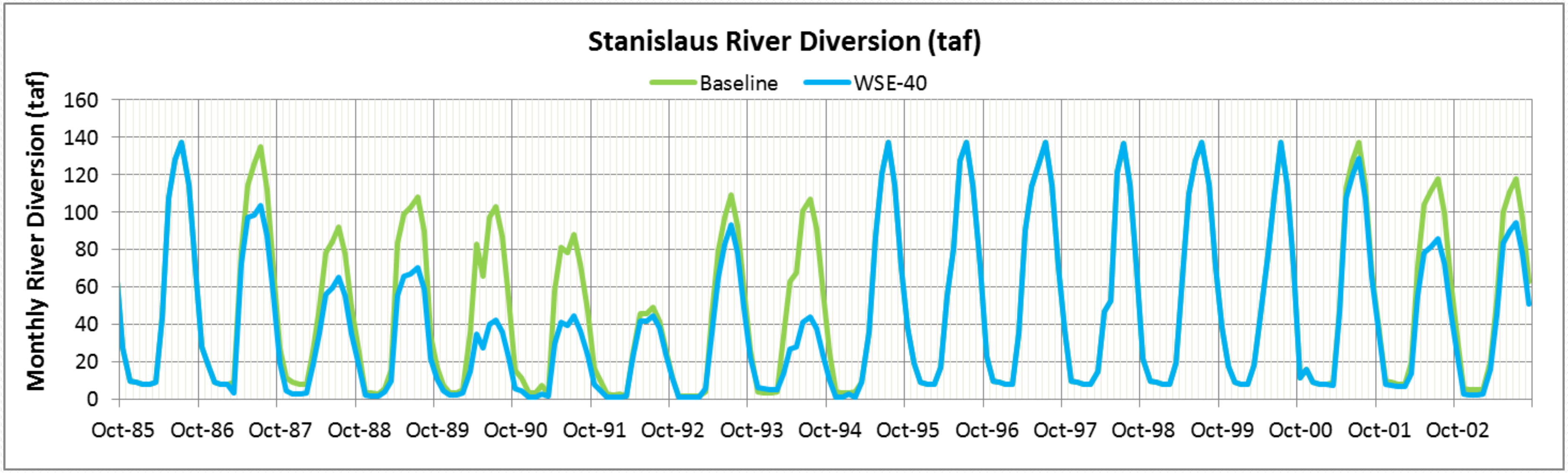
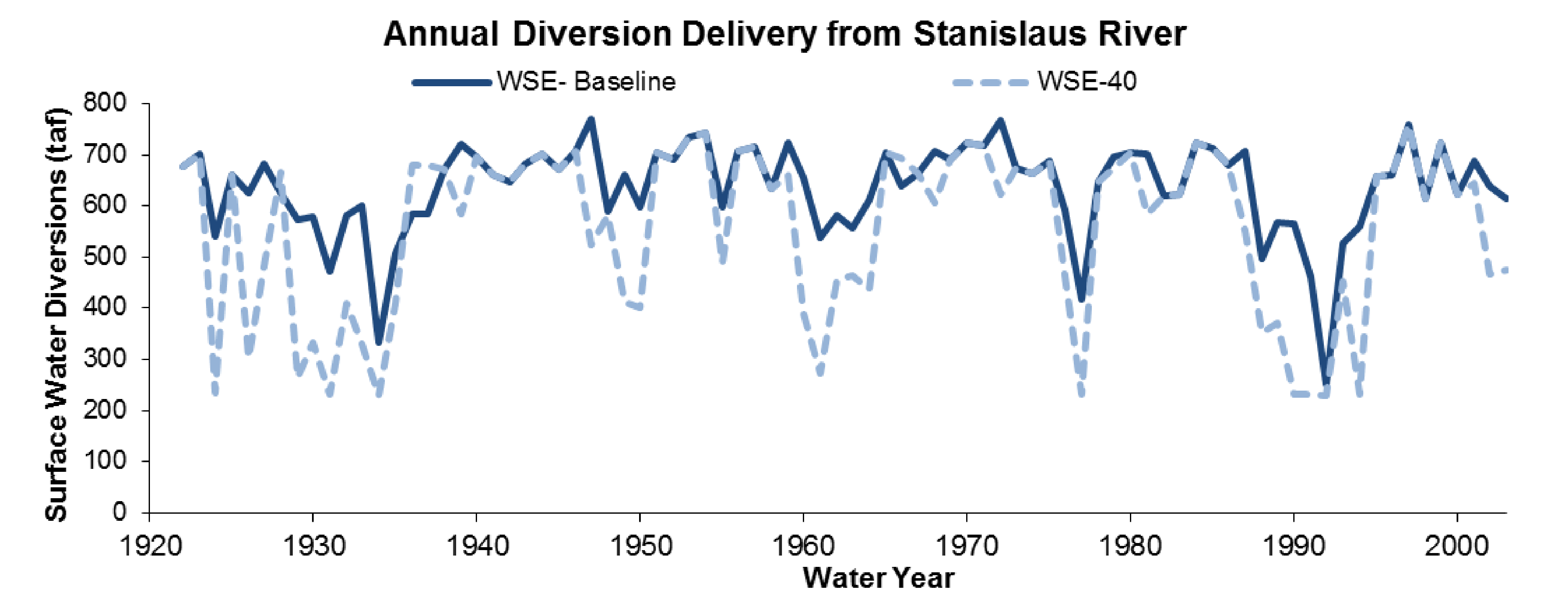
Stanislaus River Total Diversions, WY 1986-2003



Stanislaus WSE Baseline vs. WSE-40: Annual Total Diversions (WY 1922- 2003)



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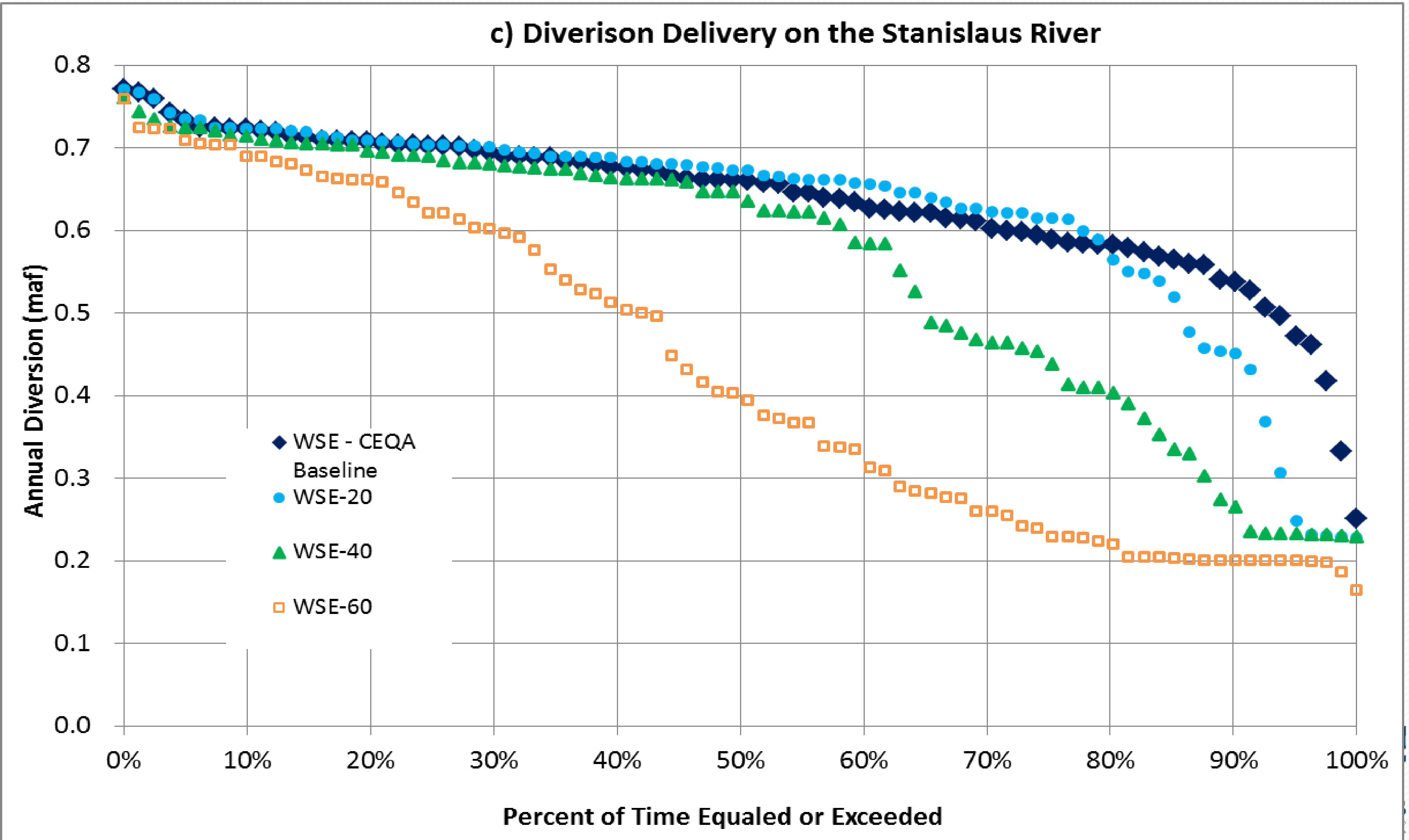
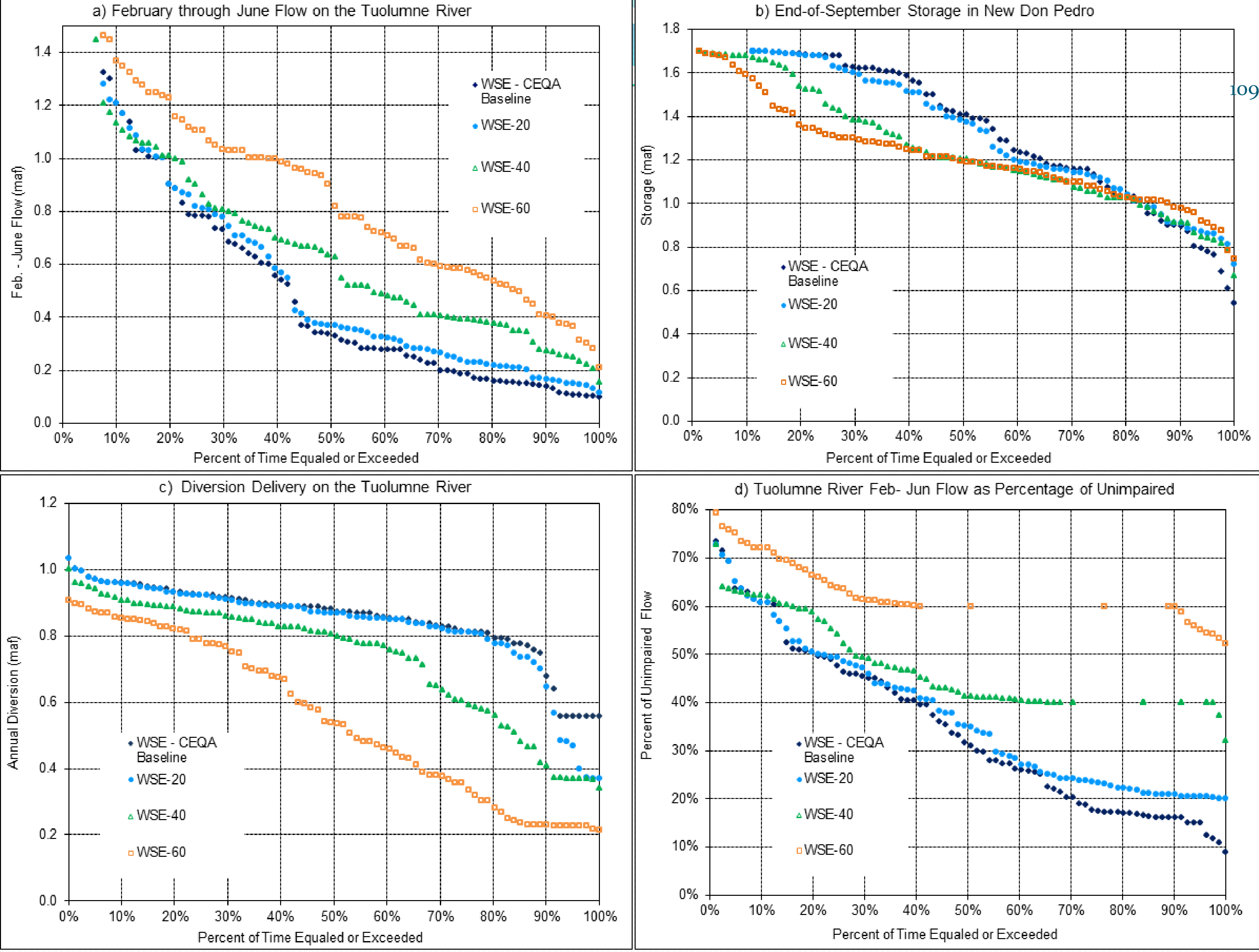
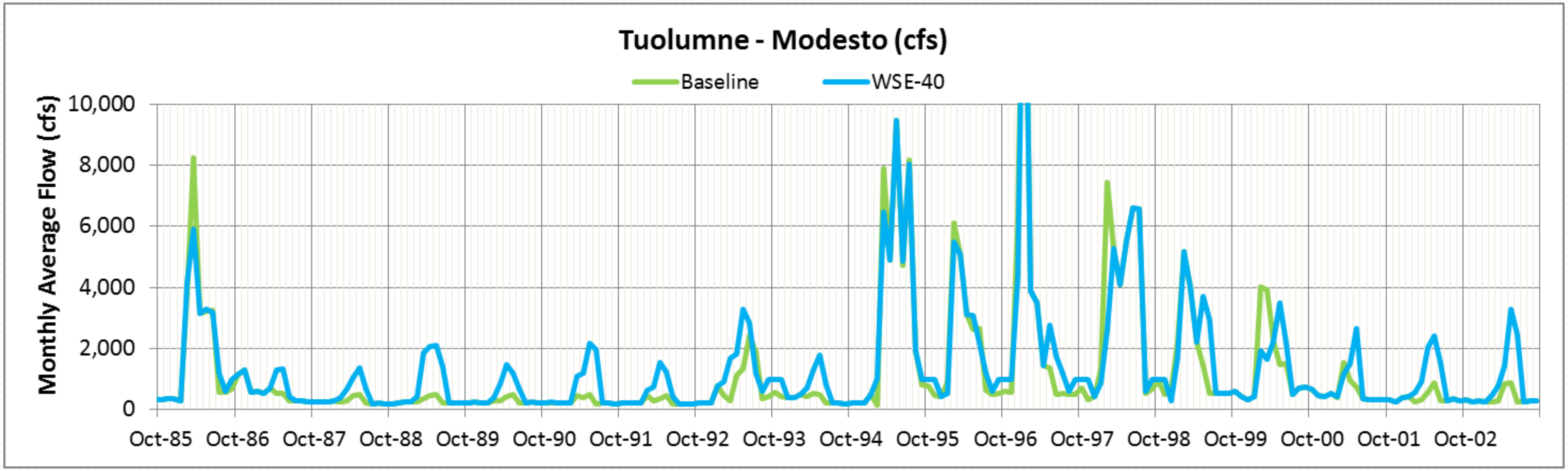
Diversion Exceedence in WSE Alternatives

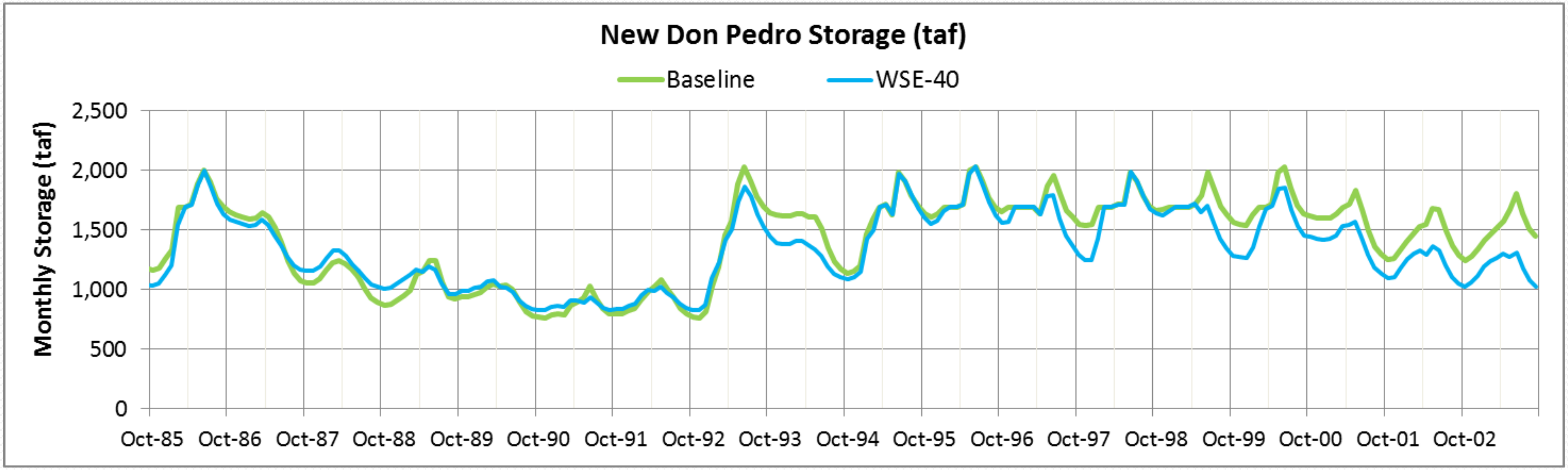



a) February through June Flow on the Tuolumne River
Feb. - June Flow (maf)
Percent of Time Equaled or Exceeded
WSE - CEQA Baseline
WSE-20
WSE-40
WSE-60
b) End-of-September Storage in New Don Pedro
Storage (maf)
Percent of Time Equaled or Exceeded
WSE - CEQA Baseline
WSE-20
WSE-40
WSE-60
c) Diversion Delivery on the Tuolumne River
Annual Diversion (maf)
Percent of Time Equaled or Exceeded
WSE - CEQA Baseline
WSE-20
WSE-40
WSE-60
d) Tuolumne River Feb- Jun Flow as Percentage of Unimpaired
Percent of Unimpaired Flow
Percent of Time Equaled or Exceeded
WSE - CEQA Baseline
WSE-20
WSE-40
WSE-60

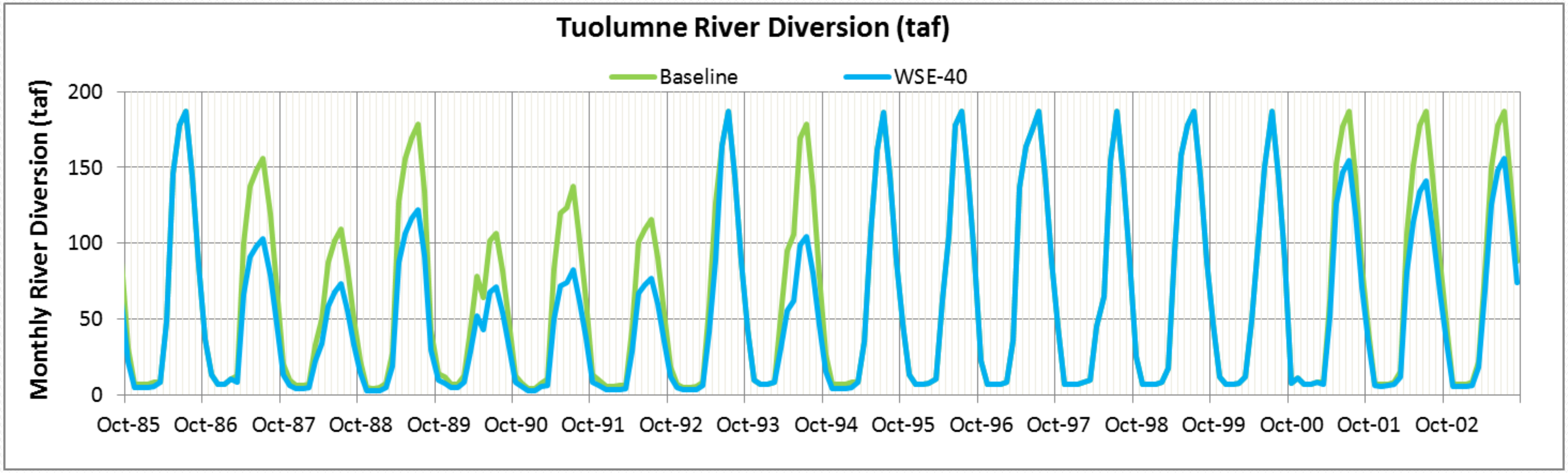
Tuolumne River at Modesto Instream Flow, WY 1986-2003



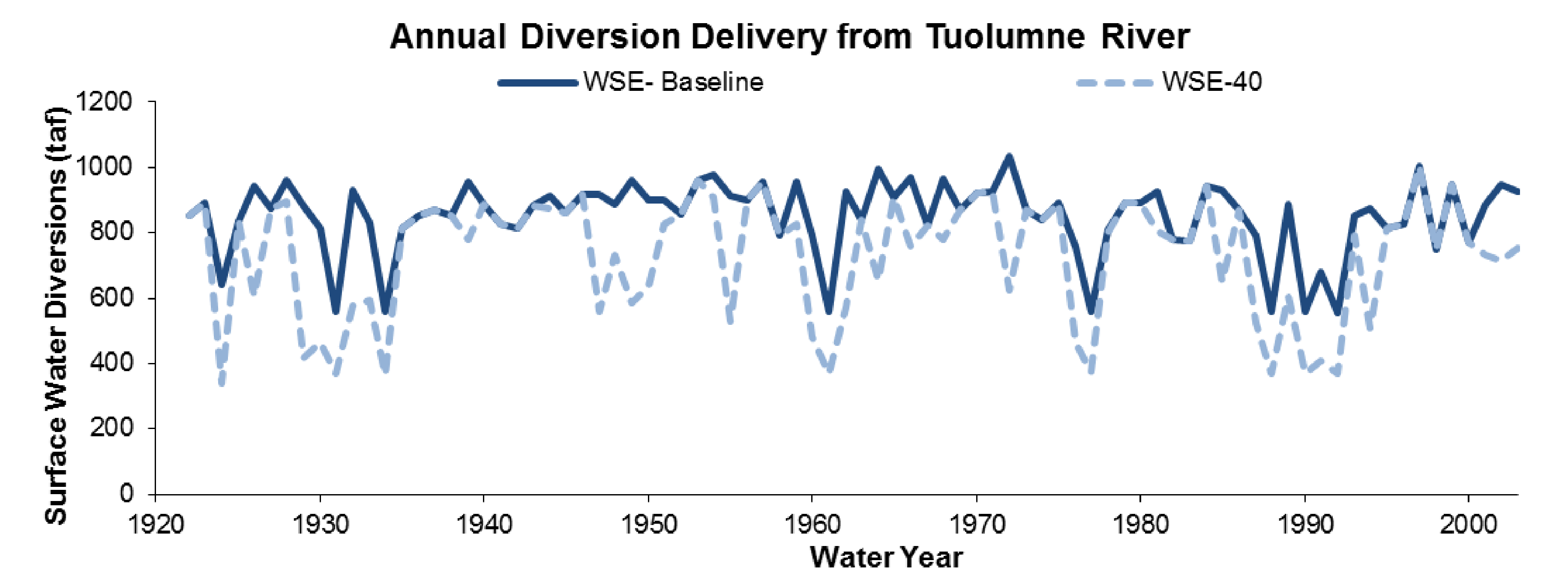
Tuolumne River, New Don Pedro Res. Storage Conditions, WY 1986-2003



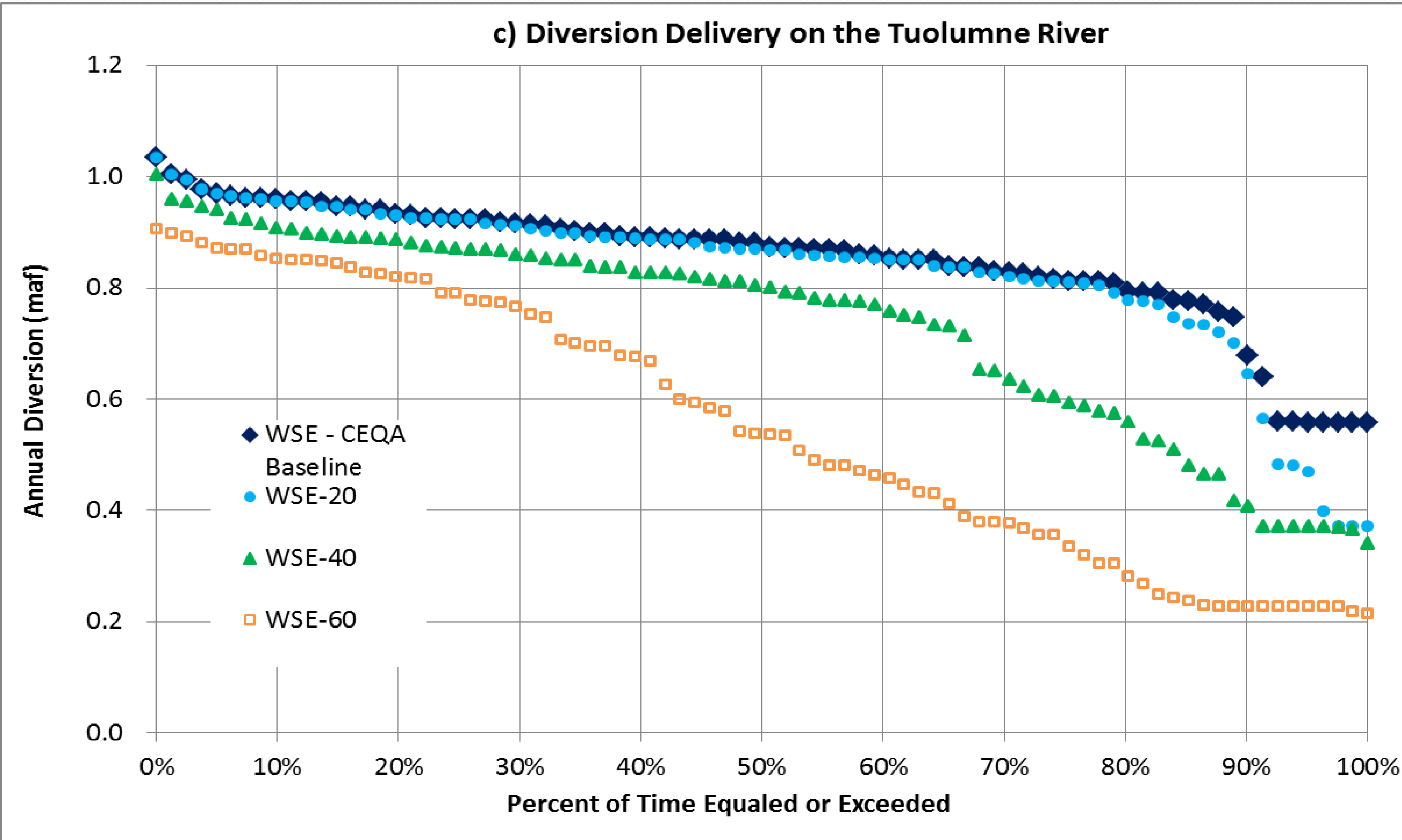
Tuolumne River Total Diversions, WY 1986-2003

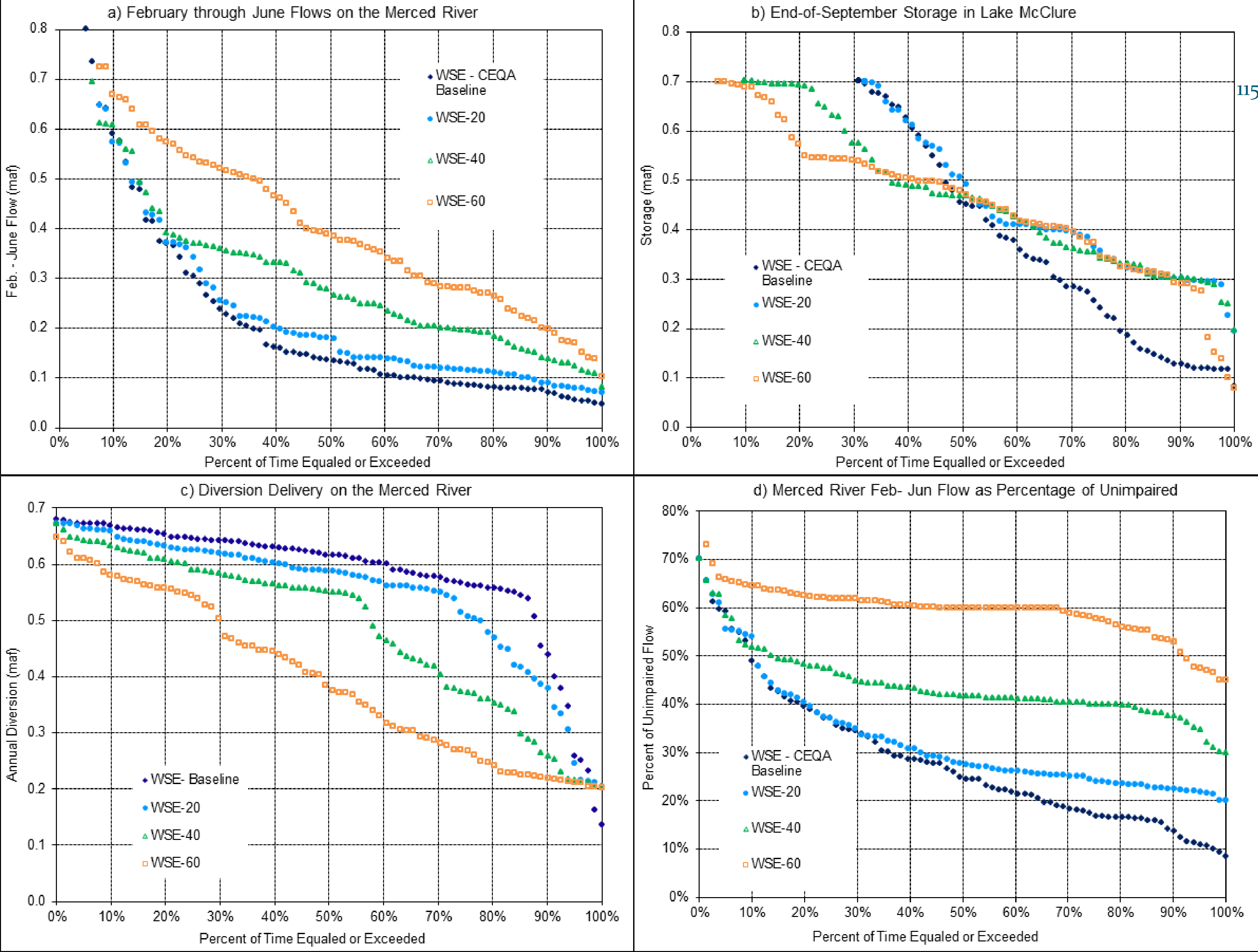


Tuolumne WSE Baseline vs. WSE-40: Annual Total Diversions (WY 1922- 2003)

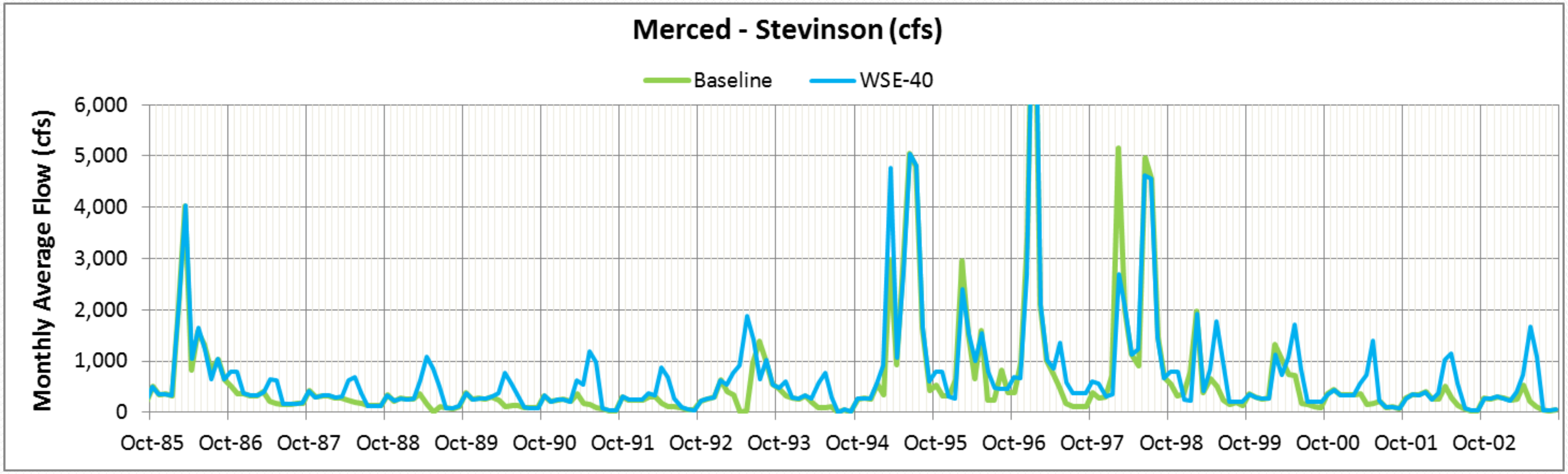


Diversion Exceedence in WSE Alternatives




a) February through June Flows on the Merced River
Feb. - June Flow (maf)
Percent of Time Equaled or Exceeded
WSE - CEQA Baseline
WSE-20
WSE-40
WSE-60
b) End-of-September Storage in Lake McClure
Storage (maf)
Percent of Time Equalled or Exceeded
WSE - CEQA Baseline
WSE-20
WSE-40
WSE-60
c) Diversion Delivery on the Merced River
Annual Diversion (maf)
Percent of Time Equaled or Exceeded
WSE- Baseline
WSE-20
WSE-40
WSE-60
d) Merced River Feb- Jun Flow as Percentage of Unimpaired
Percent of Unimpaired Flow
Percent of Time Equaled or Exceeded
WSE - CEQA Baseline
WSE-20
WSE-40
WSE-60

Merced River at Stevinson Instream Flow WY 1986-2003



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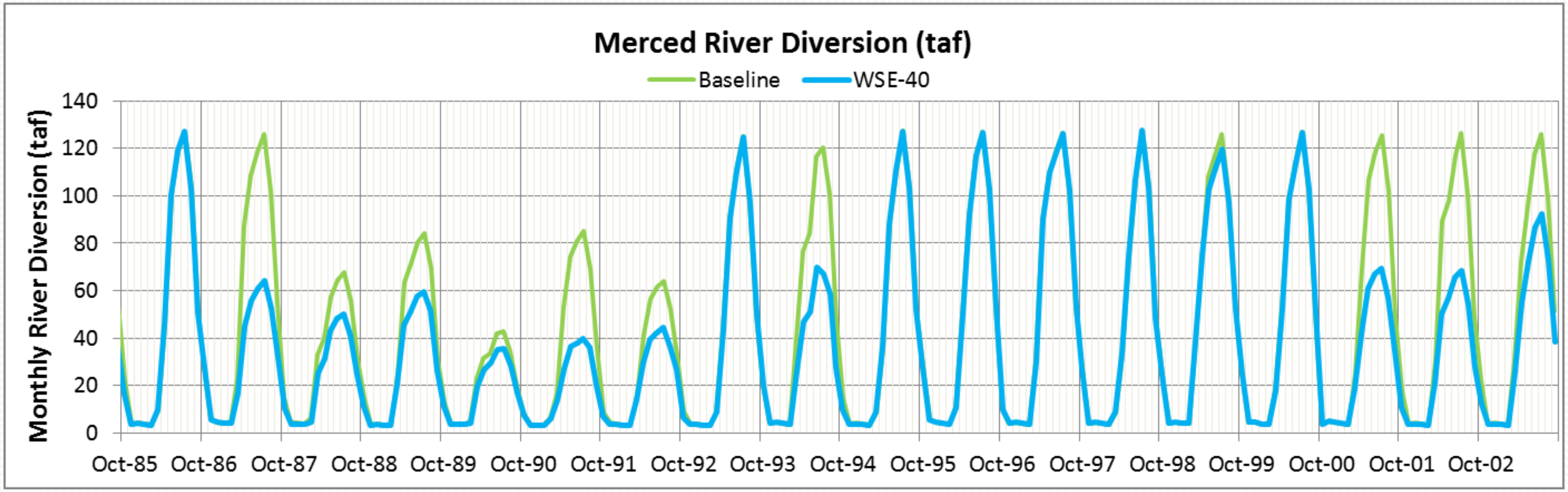
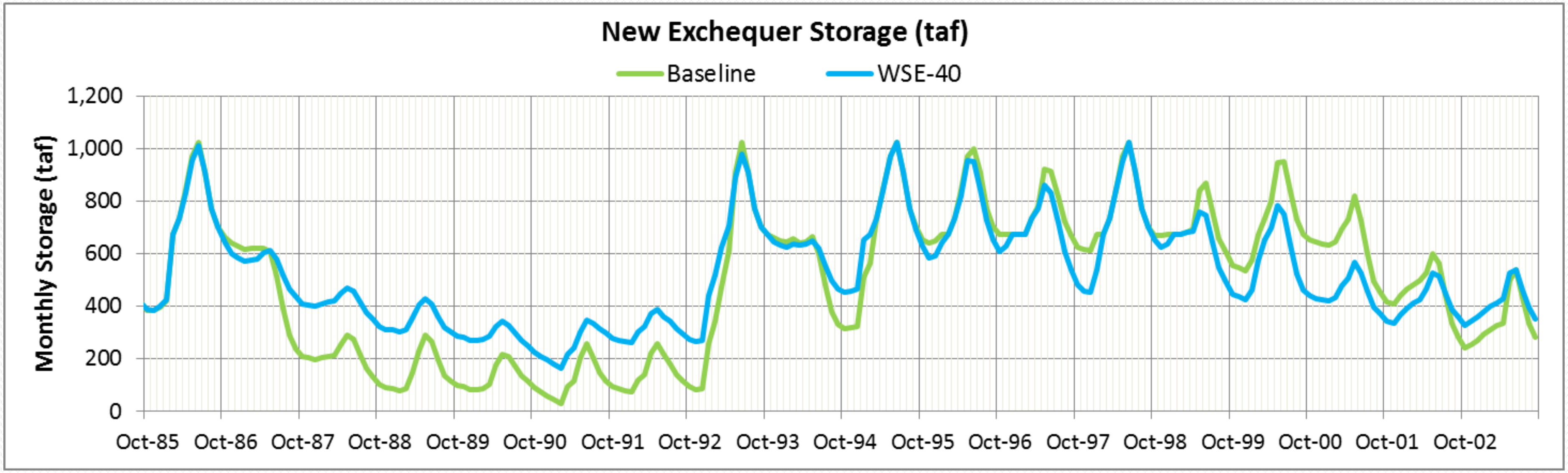
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

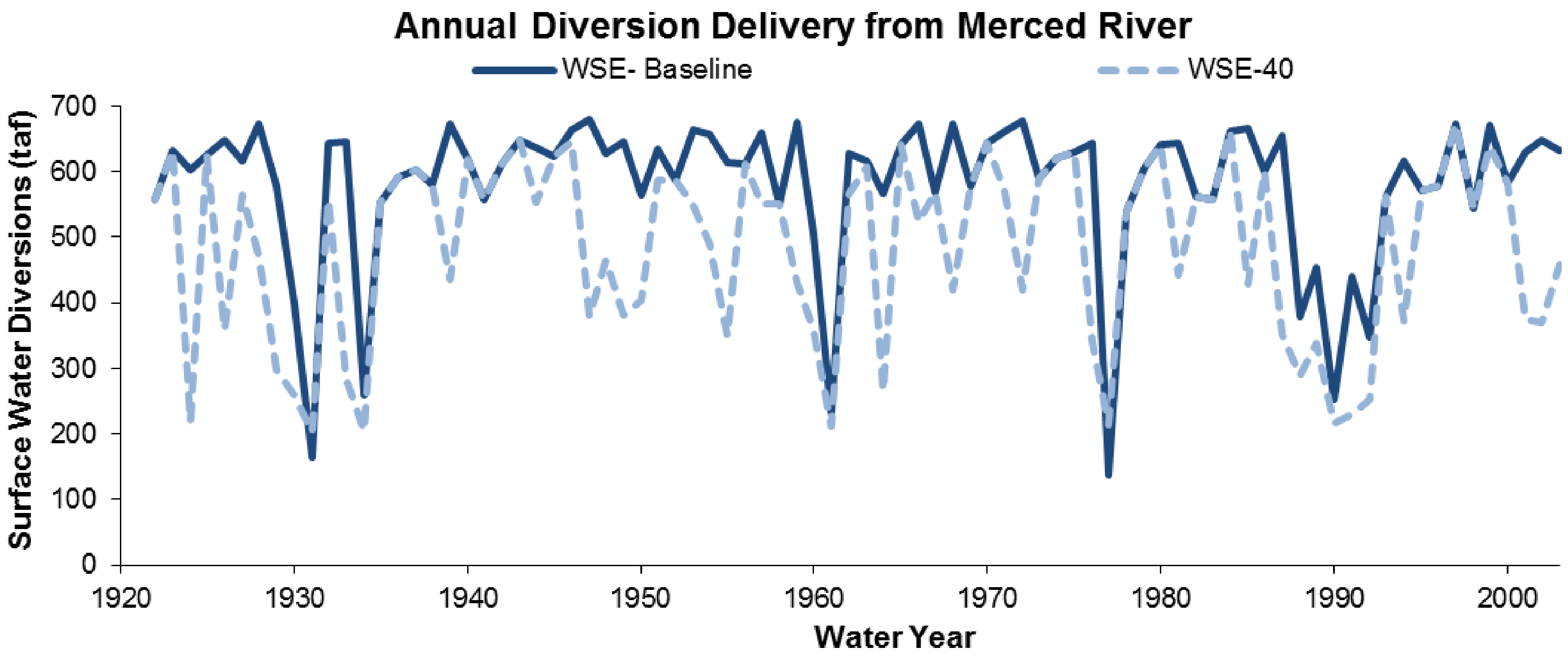
Merced River Total Diversions, WY 1986-2003



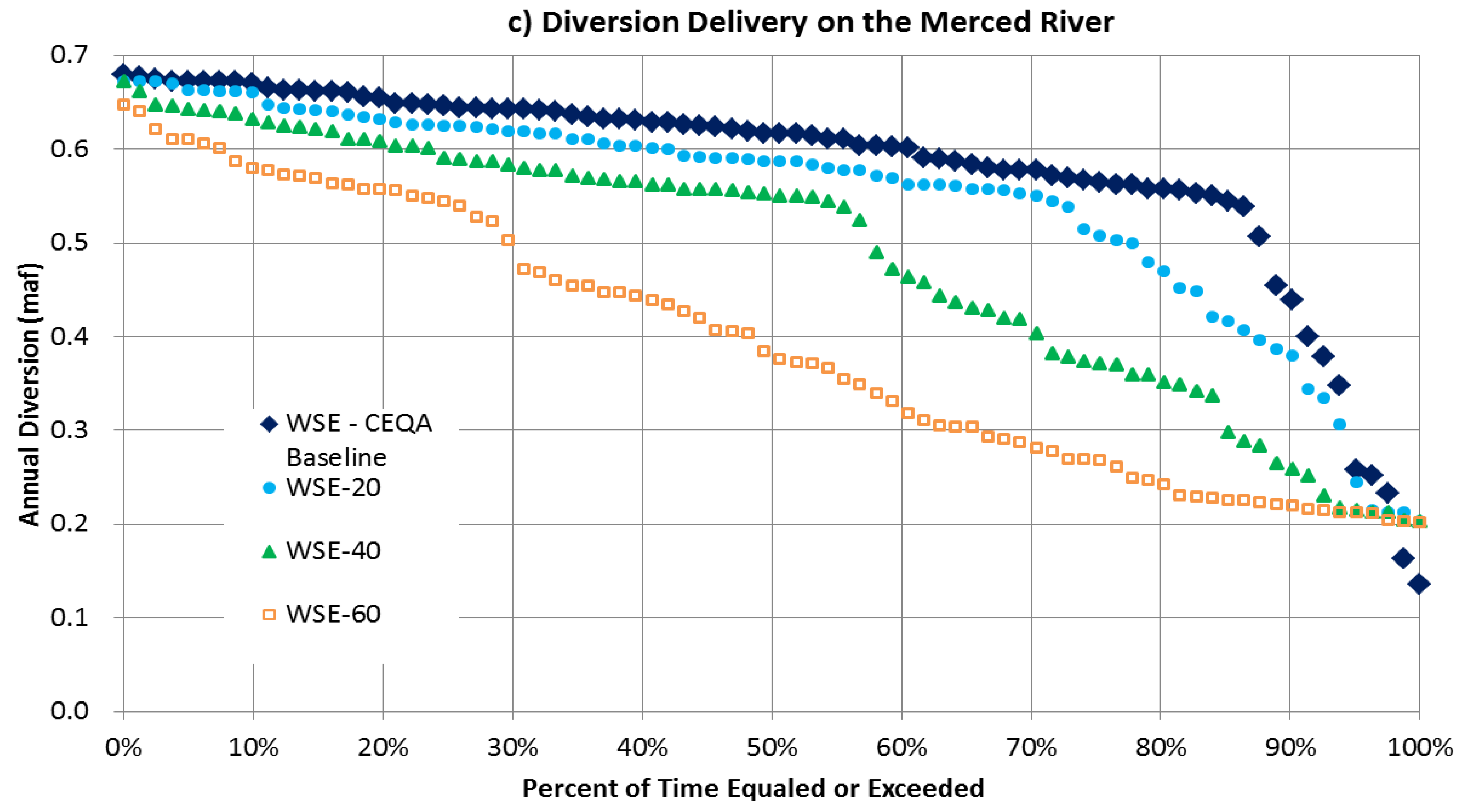
Merced River, New Exchequer Res. Storage Conditions, WY 1986-2003



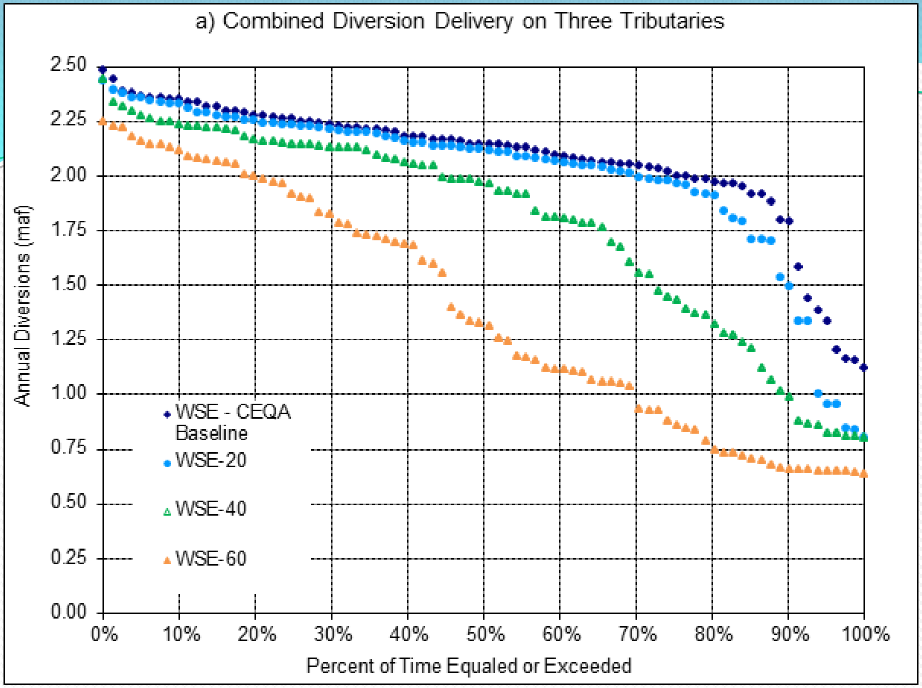
Merced WSE Baseline vs. WSE-40: Annual Total Diversions (WY 1922- 2003)

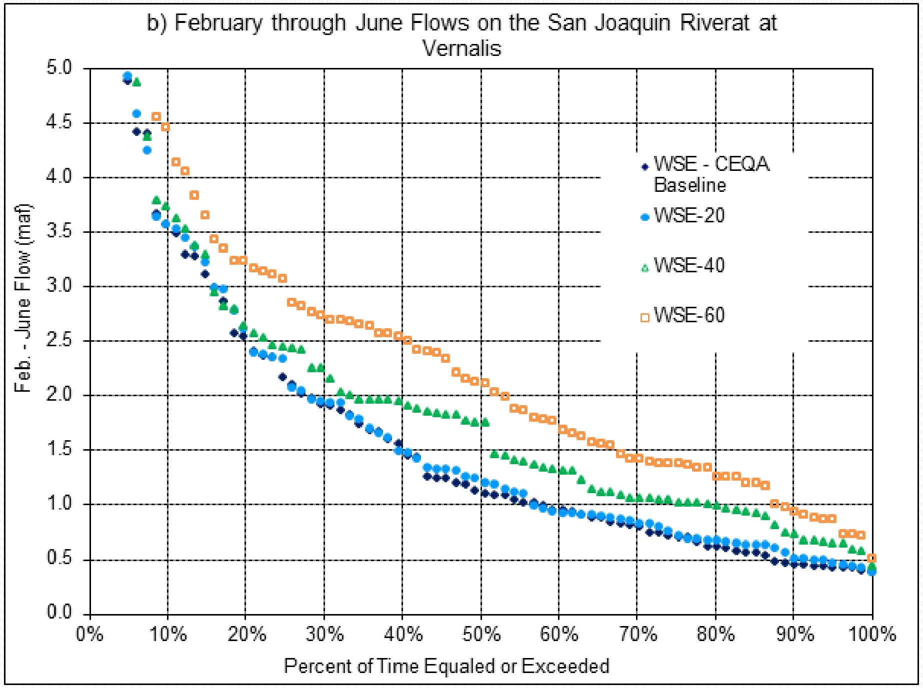


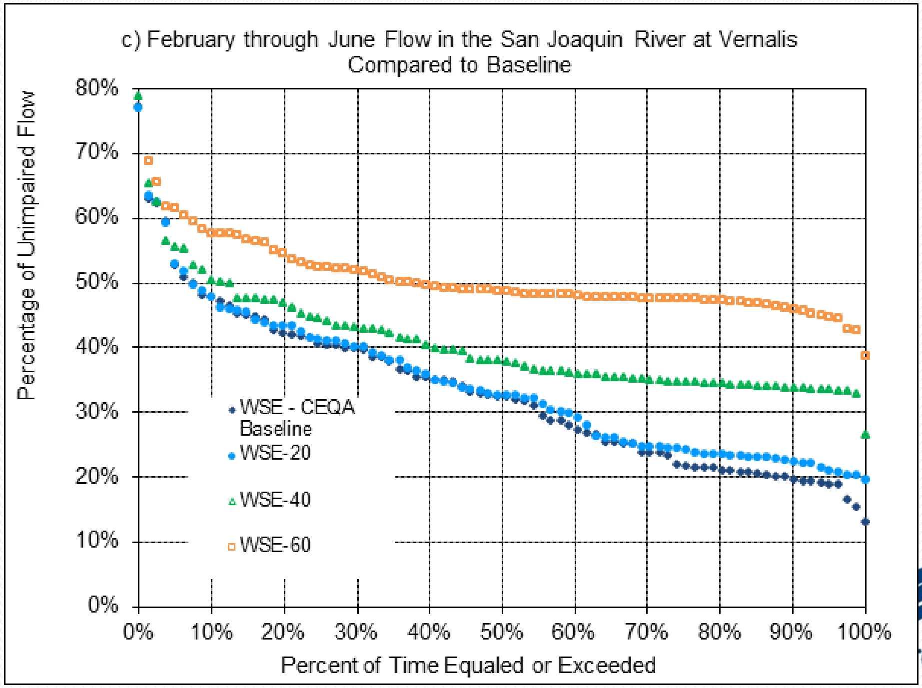
Diversion Exceedence in WSE Alternatives



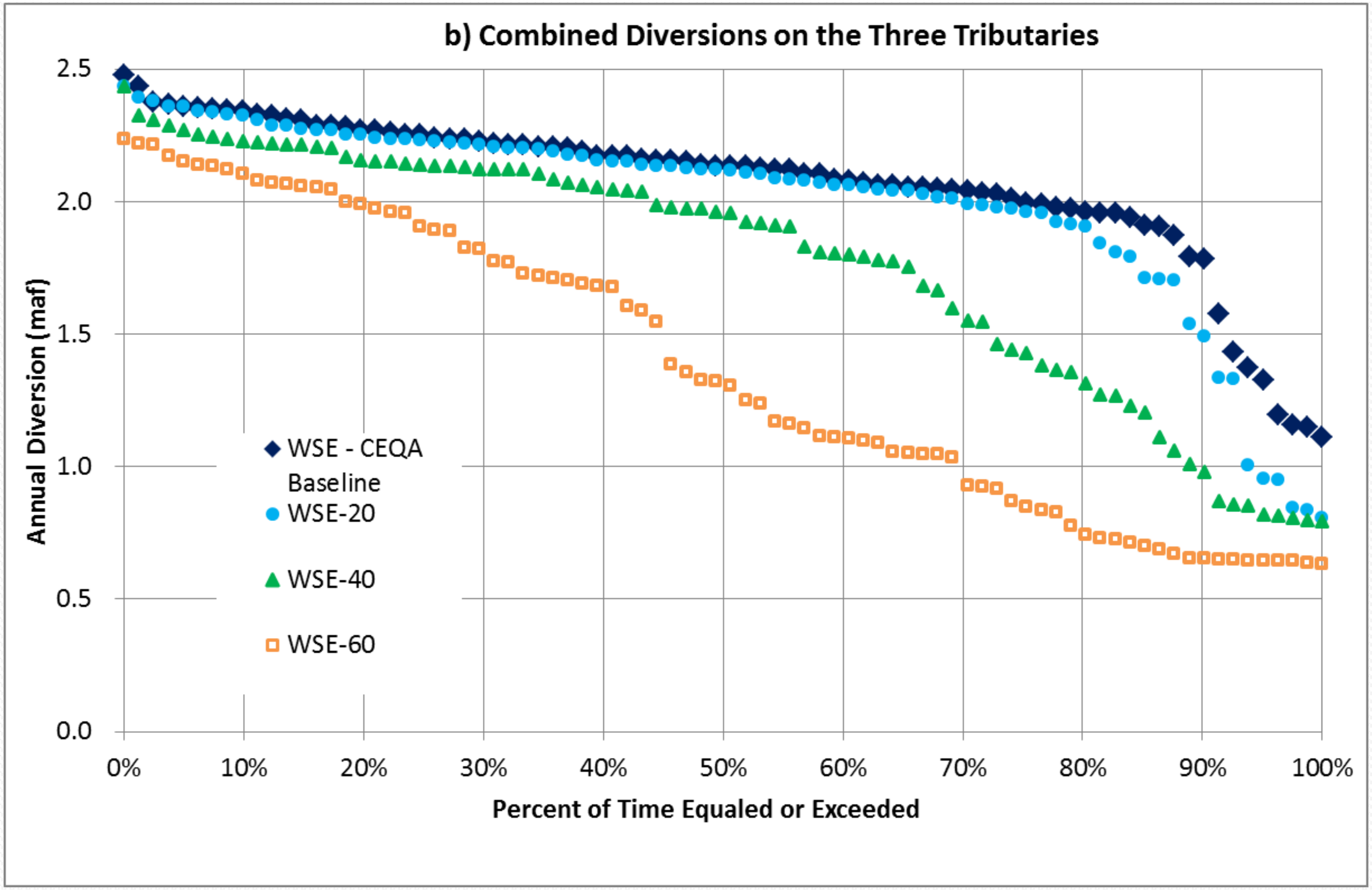
Plan Area Total Diversion & Flow Exceedences at Vernalis







Plan Area Total
Diversion Exceedence in WSE Alternatives



Estimated Effect on Average Annual Surface Water Diversion

	Stanislaus (TAF)/(%)	Tuolumne (TAF)/(%)	Merced (TAF)/(%)	Total (TAF)/(%)
Baseline	637/100	851/100	580/100	2,068/100
30% UF Objective	-33/-5	-56/-7	-60/-10	-149/-7
40% UF Objective	-79/-12	-119 /-14	-95/-16	**-293/-14**
50% UF Objective	-136 / -21	-193/-23	-136/ -23	-465/-23

TAF = thousand acre-feet per year

Summary of Mean Annual Water Supply Effects (Table ES-2)

		Baseline	Percent of Unimpaired Flow								
		Diversion	20%	25%	30%	35%	40%	45%	50%	55%	60%
Stanislaus	Volume (TAF)	637	624	616	604	592	558	540	500	470	431
	Change (TAF)		-12	-20	-33	-45	-79	-97	-136	-167	-206
	Change (%)		-2	-3	-5	-7	-12	-15	-21	-26	-32
Tuolumne	Volume (TAF)	851	831	819	795	769	732	701	657	610	553
	Change (TAF)		-20	-32	-56	-82	-119	-149	-193	-240	-298
	Change (%)		-2	-4	-7	-10	-14	-18	-23	-28	-35
Merced	Volume (TAF)	580	547	536	520	505	485	470	444	422	395
	Change (TAF)		-33	-44	-60	-75	-95	-111	-136	-159	-185
	Change (%)		-6	-8	-10	-13	-16	-19	-23	-27	-32
Plan Area (Total of Three Tributaries)	Volume (TAF)	2,068	2,002	1,972	1,919	1,866	1,775	1,711	1,602	1,502	1,379
	Change (TAF)		-65	-96	-149	-202	-293	-357	-465	-566	-689
	Change (%)		-3	-5	-7	-10	-14	-17	-23	-27	-33

Note: Gray shading highlights numbers that are discussed in the text.

TAF = thousand acre-feet

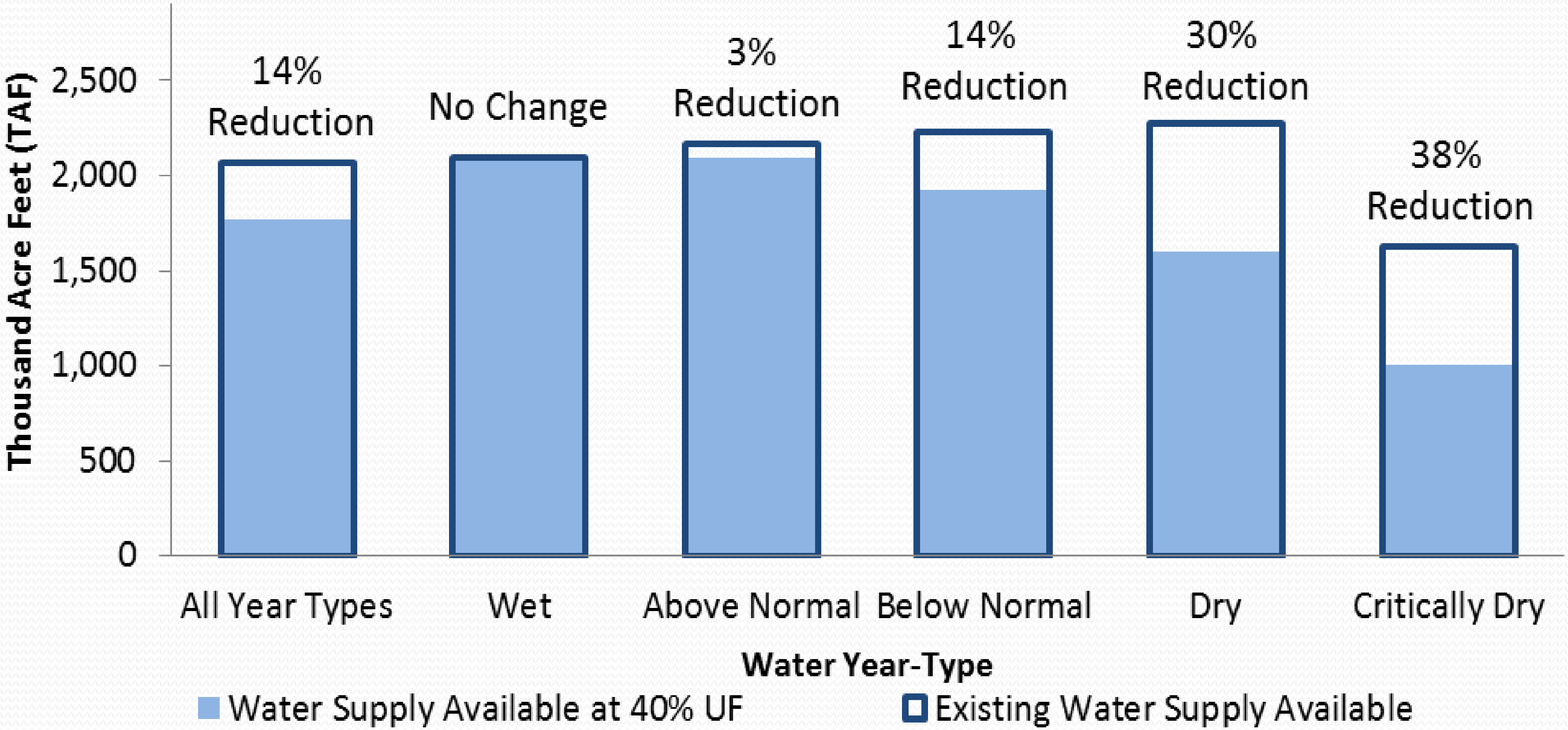
Mean Annual Water Supply Effects of LSJR Alternative 3 (40 Percent Unimpaired Flow Proposal) by Water Year Type (Table ES-3)

		Year Type				
		Wet	Above Normal	Below Normal	Dry	Critically Dry
Stanislaus	Baseline (TAF)	661	661	661	683	520
	LSJR Alt 3 (40% UF) (TAF)	662	630	613	536	303
	Change (TAF)	1	-31	-48	-147	-217
	Change (%)	0%	-5%	-7%	-22%	-42%
Tuolumne	Baseline (TAF)	848	882	931	938	689
	LSJR Alt 3 (40% UF) (TAF)	845	855	800	681	426
	Change (TAF)	-3	-27	-131	-257	-263
	Change (%)	0%	-3%	-14%	-27%	-38%
Merced	Baseline (TAF)	591	622	642	650	416
	LSJR Alt 3 (40% UF) (TAF)	591	607	508	381	272
	Change (TAF)	0	-15	-134	-268	-144
	Change (%)	0%	-2%	-21%	-41%	-35%
Plan Area (Total of Three Tributaries)	Baseline (TAF)	2,099	2,164	2,233	2,271	1,625
	LSJR Alt 3 (40% UF) (TAF)	2,097	2,091	1,921	1,598	1,001
	Change (TAF)	-2	-73	-313	-673	-624
	Change (%)	0%	-3%	-14%	-30%	-38%

TAF = thousand acre-feet
UF = unimpaired flow

CALIFORNIA Water Boards

Reduction in Surface Water Availability by Water Year Type (40% UF)



End of Part 2: Questions

Staff Technical Workshop Part 3:
HEC-5Q Temperature Model and Results

Analytical Tools Used to Develop the Amendment to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary and Supporting Revised Substitute Environmental Document (SED)

December 5, 2016

HEC-5Q Temperature Model

- Background
- Import of CALSIM / WSE streamflows
- Temperature results
- Effects of Reduced Spills
- Effects of Flow Shifting
- Other Noteable Effects
- Evaluation of Temperature Criteria

San Joaquin River Basin-Wide Water Temperature Model (SJR HEC-5Q)

- US Army Corps of Engineers Hydraulic Engineering Center (HEC)
- Reservoir operations and instream temperature effects
- 2009 CALFED peer review
- Recent updates in 2013 by California Dept. of Fish and Wildlife
- Version that uses streamflows from CALSIM flow balance / WSE model framework

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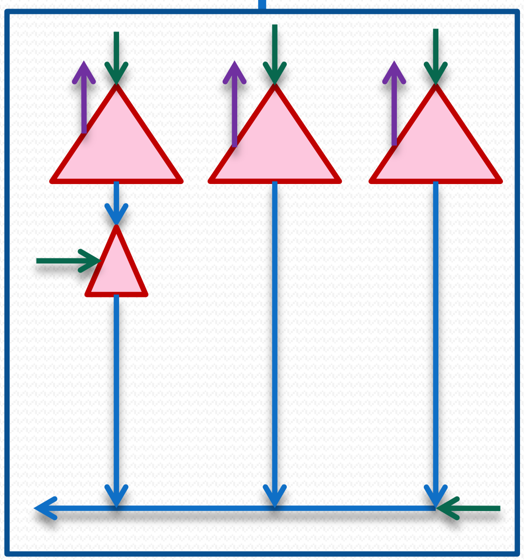
WSE Output used in SJR HEC-5Q

WSE data Stored in DSS format using HEC Excel DSS Add-in

WSE data renamed using CALSIM II Node and Link naming scheme

Convert to Daily Time Step

CALSIM to 5Q preprocessor



Monthly WSE Model Output:

- Boundary Inflows
- Reservoir Storage
- Reservoir Evaporation
- Stream Flows

HEC-5Q Temperature Model

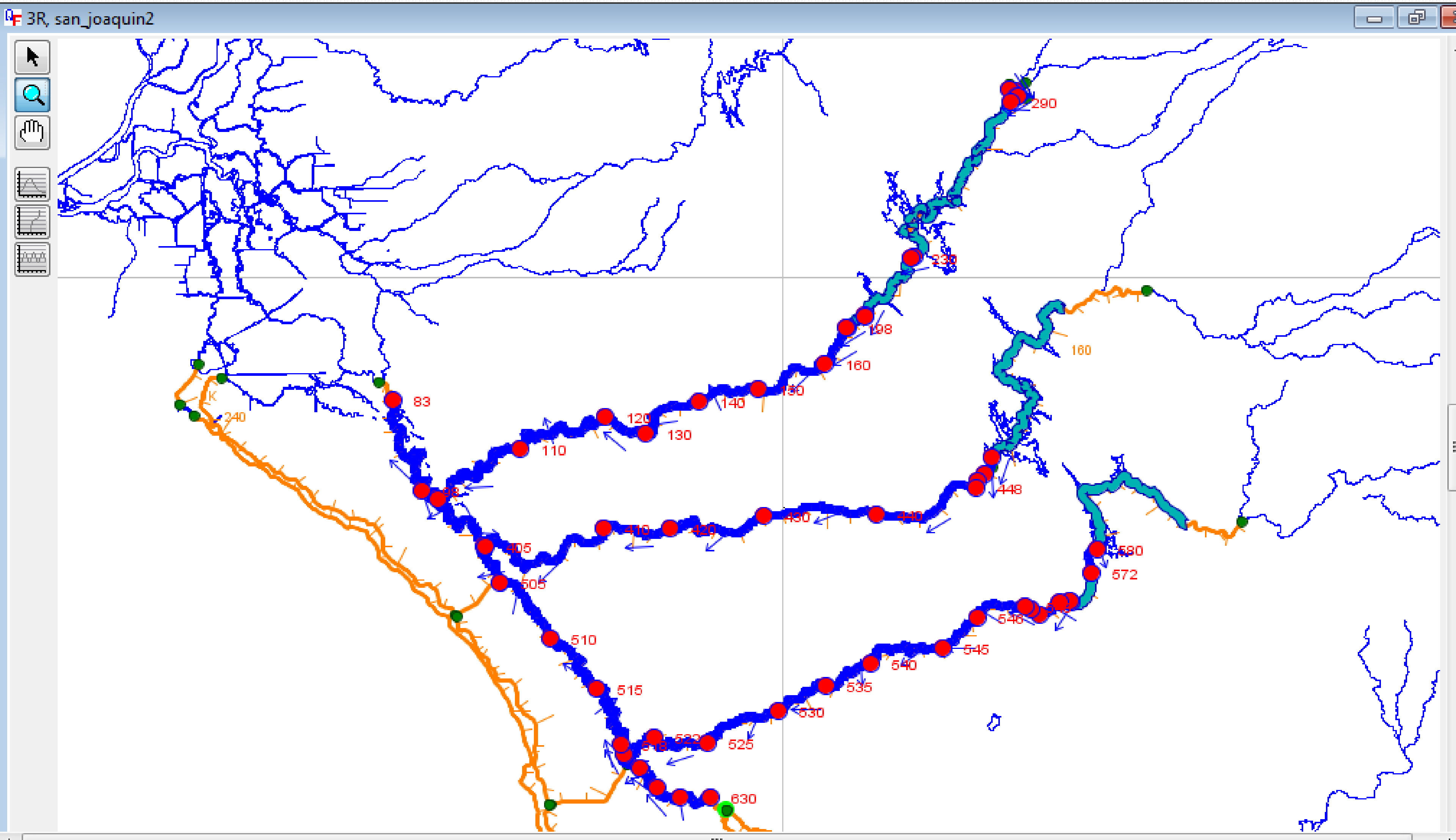
Additional parameters:

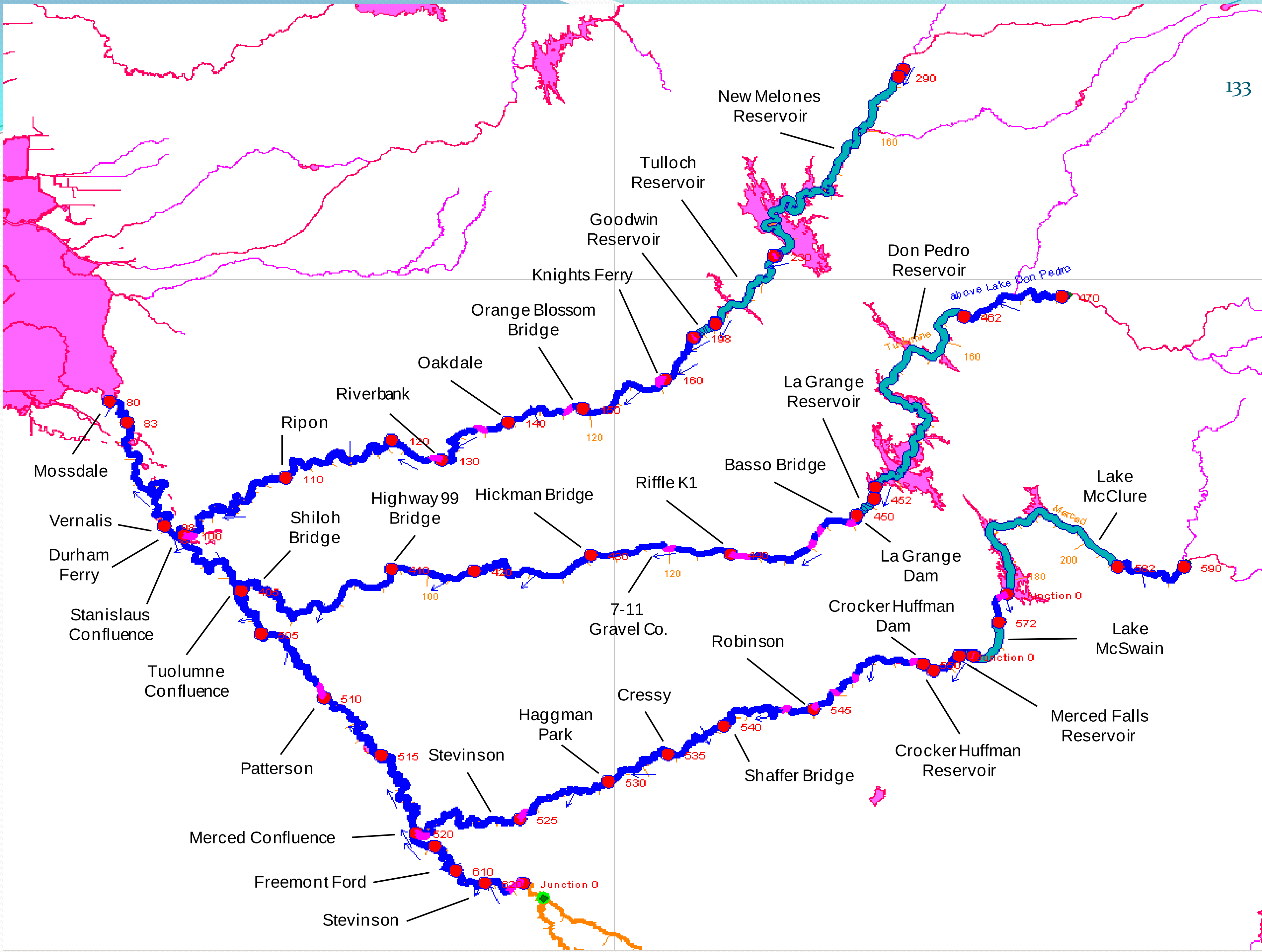
- Reservoir Temperature Profile
- Ambient Air Temperature
- Wind speed
- Local Inflows

HWMS GUI

- View System Schematic
- Edit ".RUN" Files
- Run Temp Model for Defined Alternatives
- View Results

HEC-5Q Project File 3R_Temp-opp.prj

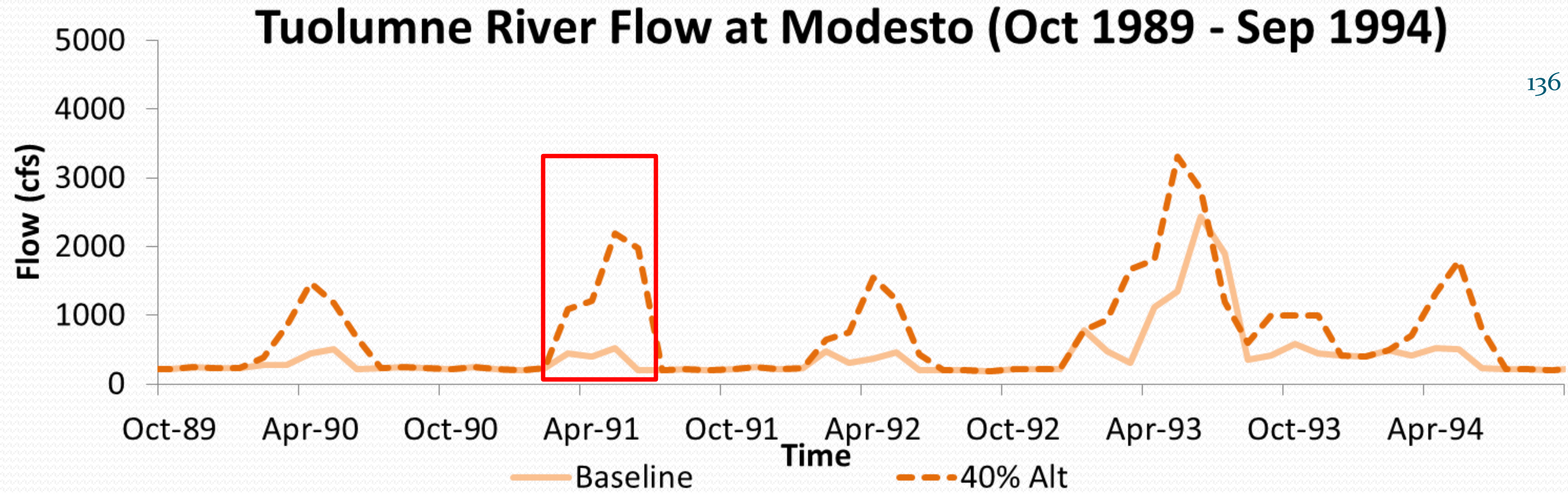



New Melones Reservoir
Tulloch Reservoir
Goodwin Reservoir
Knights Ferry
Don Pedro Reservoir
above Lake Don Pedro
Orange Blossom Bridge
Oakdale
Riverbank
Ripon
La Grange Reservoir
Mossdale
Basso Bridge
Riffle K1
Lake McClure
Highway 99 Bridge
Hickman Bridge
Vernalis
Shiloh Bridge
Durham Ferry
La Grange Dam
Stanislaus Confluence
7-11 Gravel Co.
Crocker Huffman Dam
Lake McSwain
Tuolumne Confluence
Robinson
Cressy
Merced Falls Reservoir
Haggman Park
Patterson
Stevinson
Shaffer Bridge
Crocker Huffman Reservoir
Merced Confluence
Freemont Ford
Stevinson
Junction 0

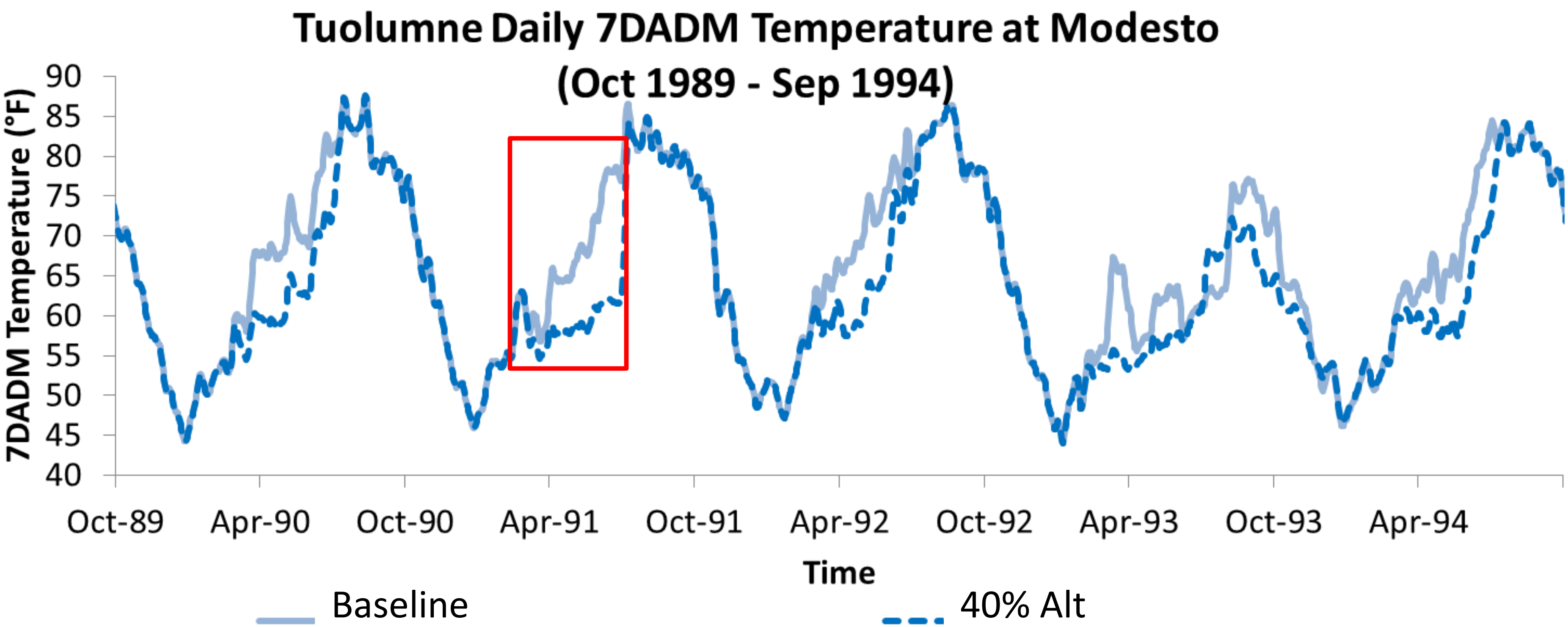
HEC-5Q Results

- 6 Predefined Alternatives set up in the temperature model (Baseline, 20%, 30%, 40%, 50%, 60% UF Objectives)
- Output temperatures for a 6 hour time step from Jan 1 1970 to Dec 31 2003
- Extended model up to 2010
- Raw Temperature Results imported to Excel using HEC DSS Add-in
- 6 hour Temperature data post-processed averaging the maximum temperatures for each day over a running 7 day period (these results are referred to as the "7 Day Average of Daily Maximum", or 7DADM, Temperatures)

Temperature Benefits of Instream Flow Alternatives

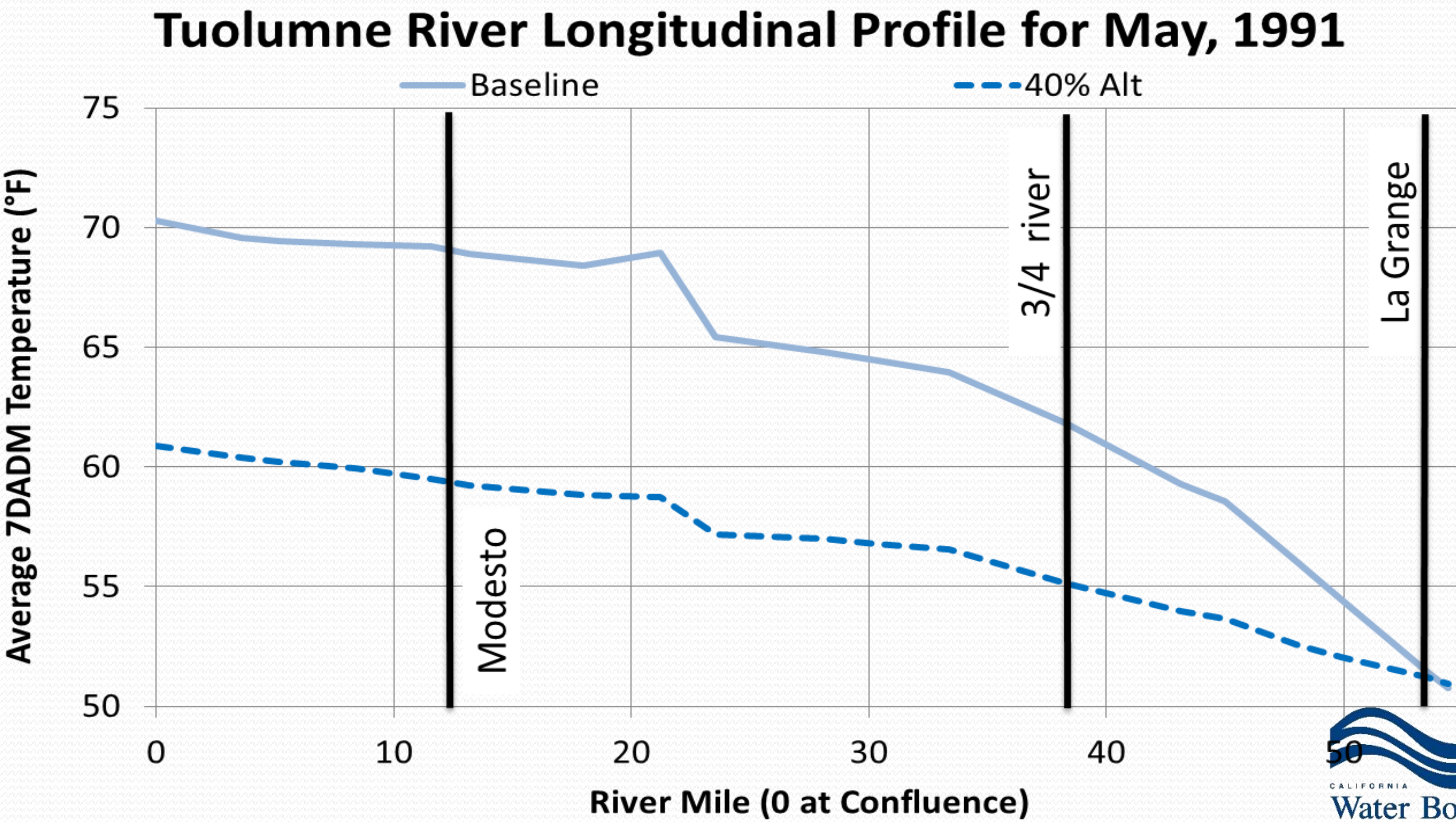


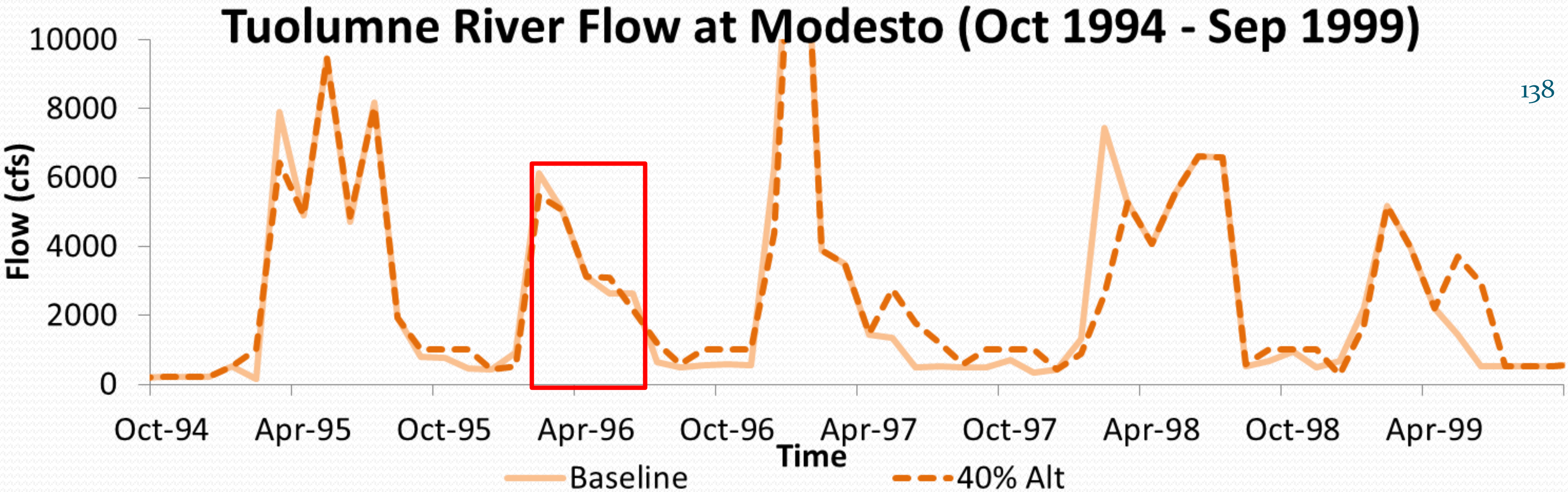
Tuolumne River Flow at Modesto (Oct 1989 - Sep 1994)
Flow (cfs)
5000
4000
3000
2000
1000
0
Oct-89
Apr-90
Oct-90
Apr-91
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Apr-94
Time
Baseline
40% Alt

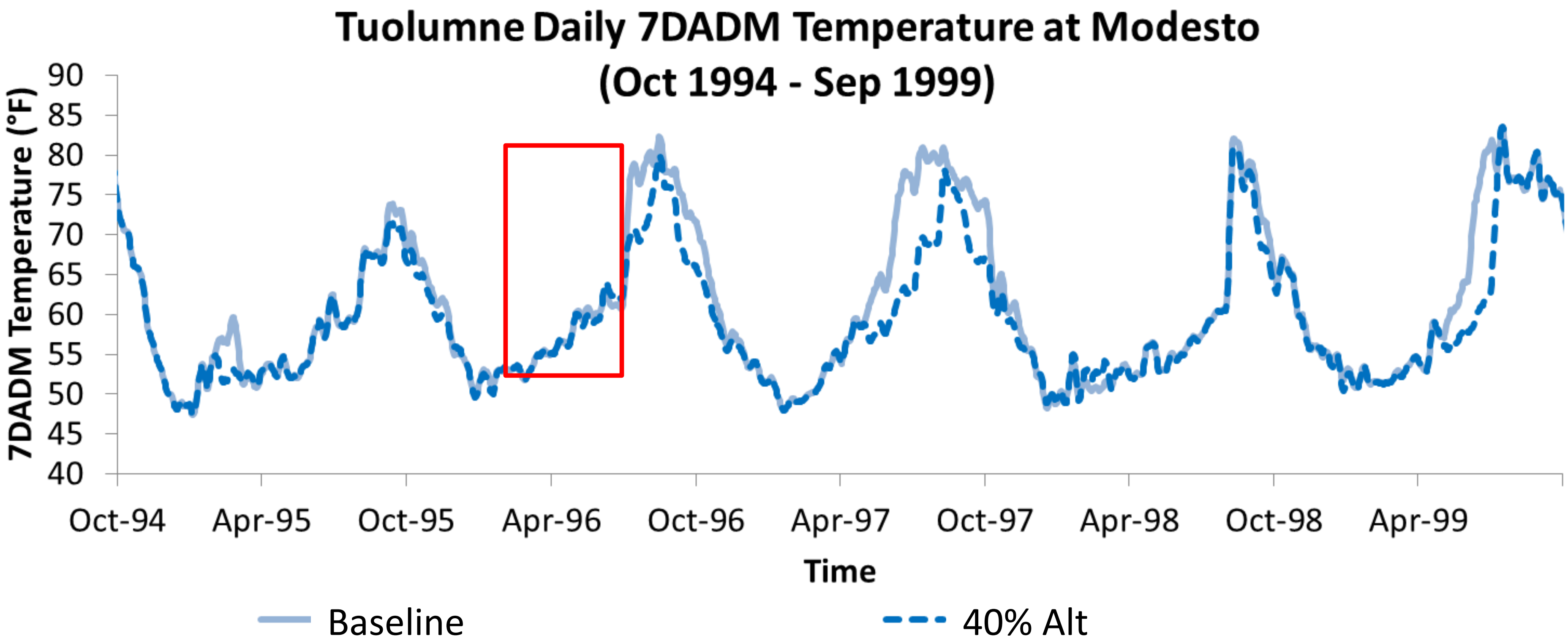


Tuolumne Daily 7DADM Temperature at Modesto
(Oct 1989 - Sep 1994)
7DADM Temperature (°F)
90
85
80
75
70
65
60
55
50
45
40
Oct-89
Apr-90
Oct-90
Apr-91
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Apr-94
Time
Baseline
40% Alt

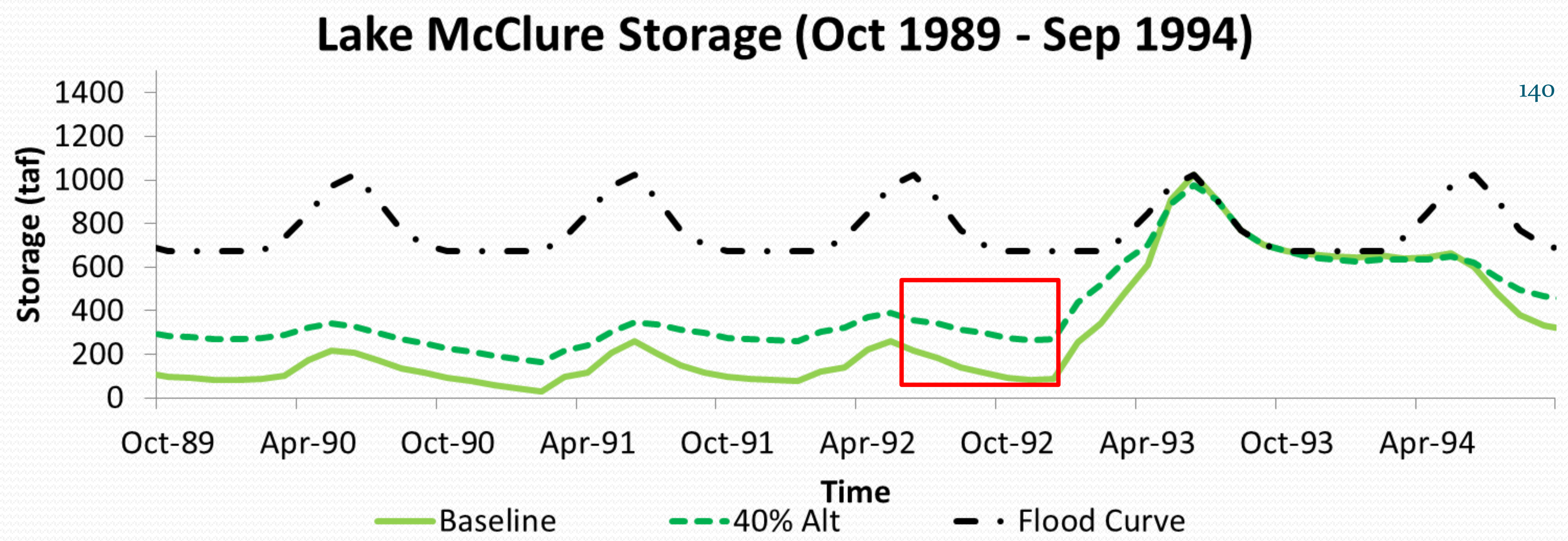
Temperature Benefit of Increased Flows

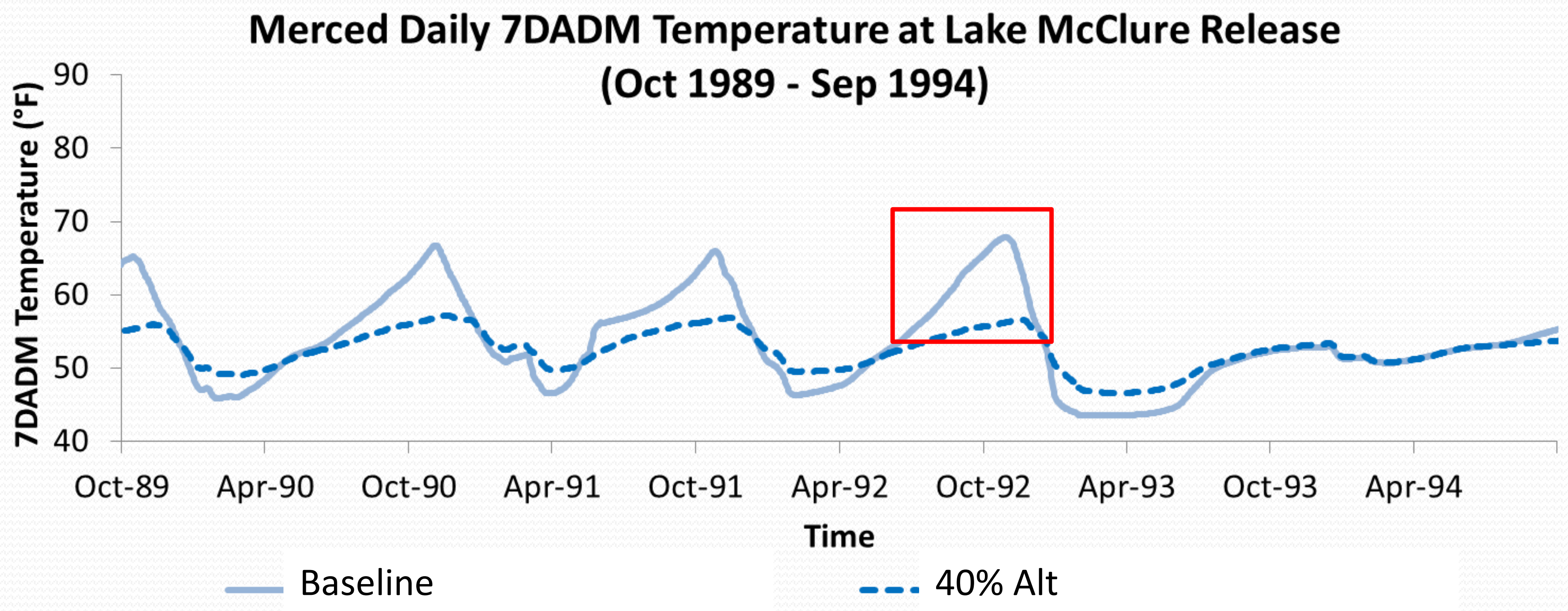



Tuolumne River Flow at Modesto (Oct 1994 - Sep 1999)
Flow (cfs)
10000
8000
6000
4000
2000
0
Oct-94
Apr-95
Oct-95
Apr-96
Oct-96
Apr-97
Oct-97
Apr-98
Oct-98
Apr-99
Time
Baseline
40% Alt

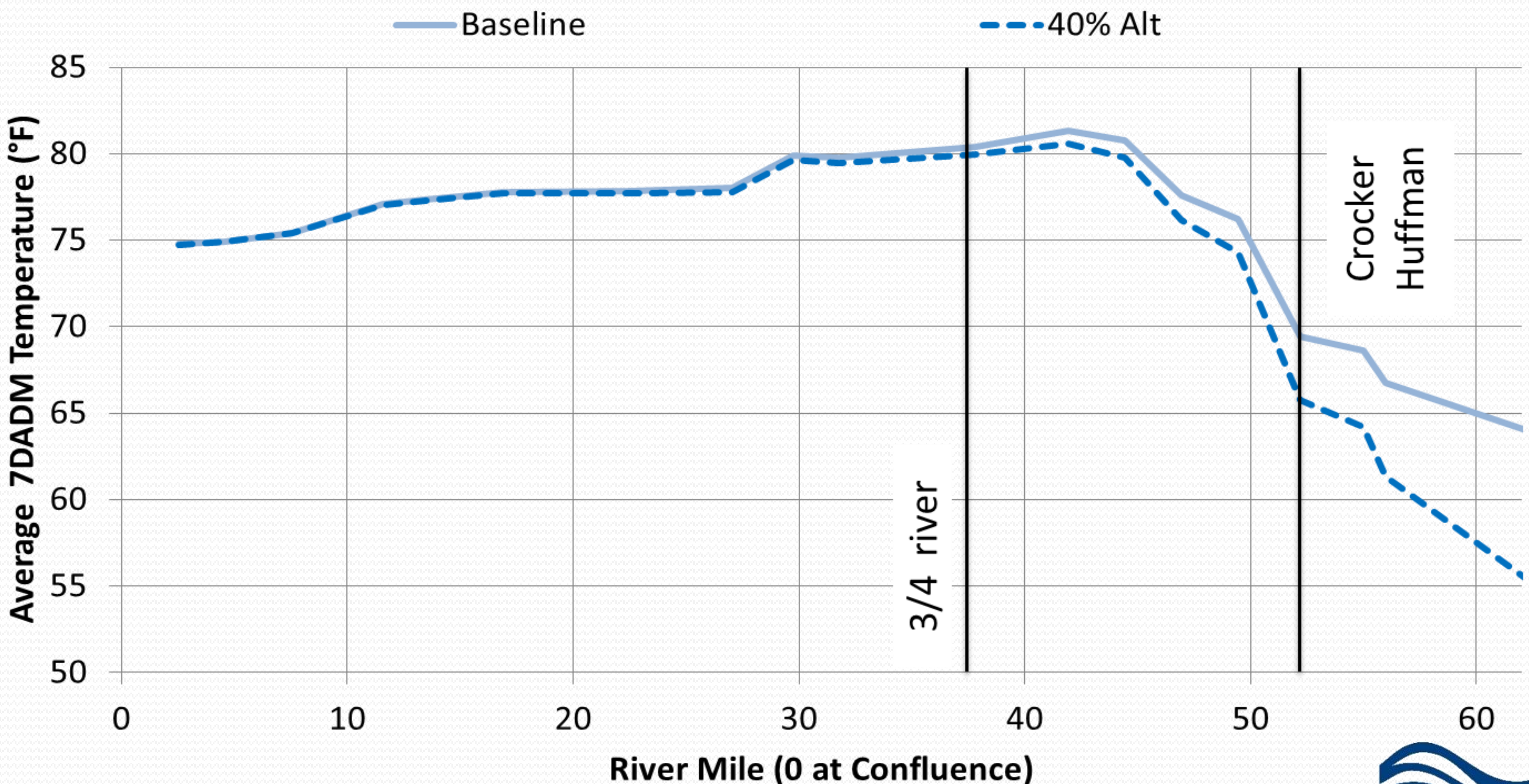

Tuolumne Daily 7DADM Temperature at Modesto
(Oct 1994 - Sep 1999)
7DADM Temperature (°F)
90
85
80
75
70
65
60
55
50
45
40
Oct-94
Apr-95
Oct-95
Apr-96
Oct-96
Apr-97
Oct-97
Apr-98
Oct-98
Apr-99
Time
Baseline
40% Alt

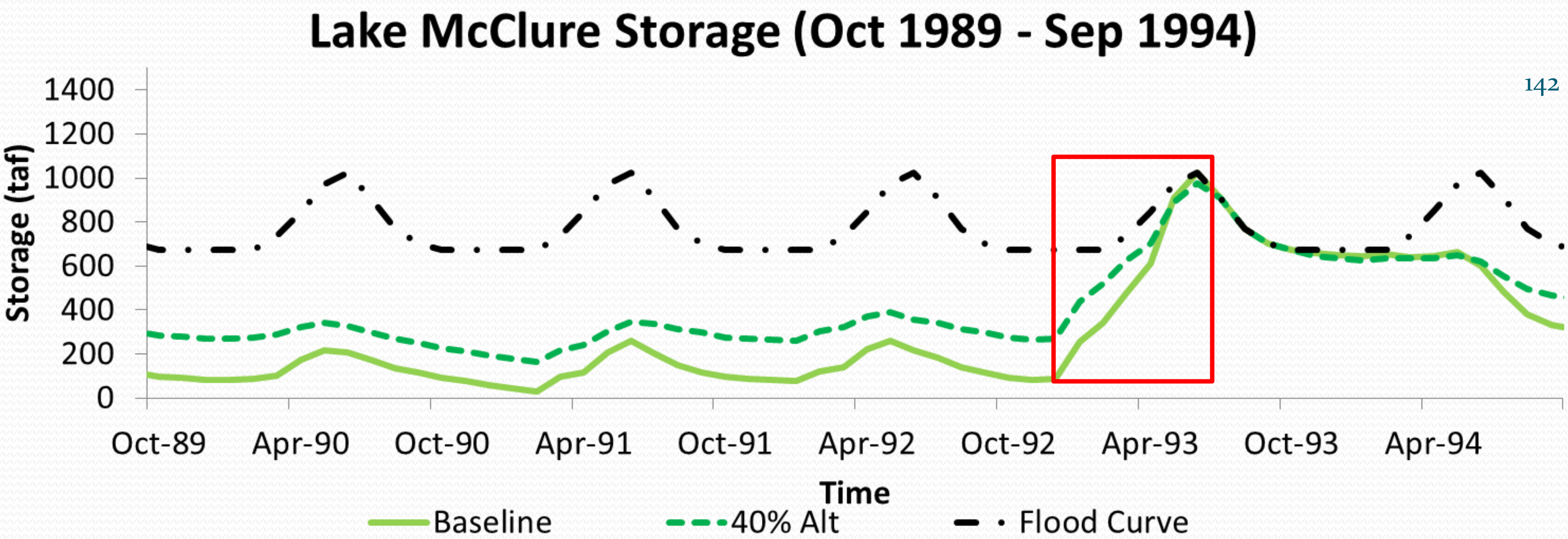
Dynamics of Reservoir Storage Levels

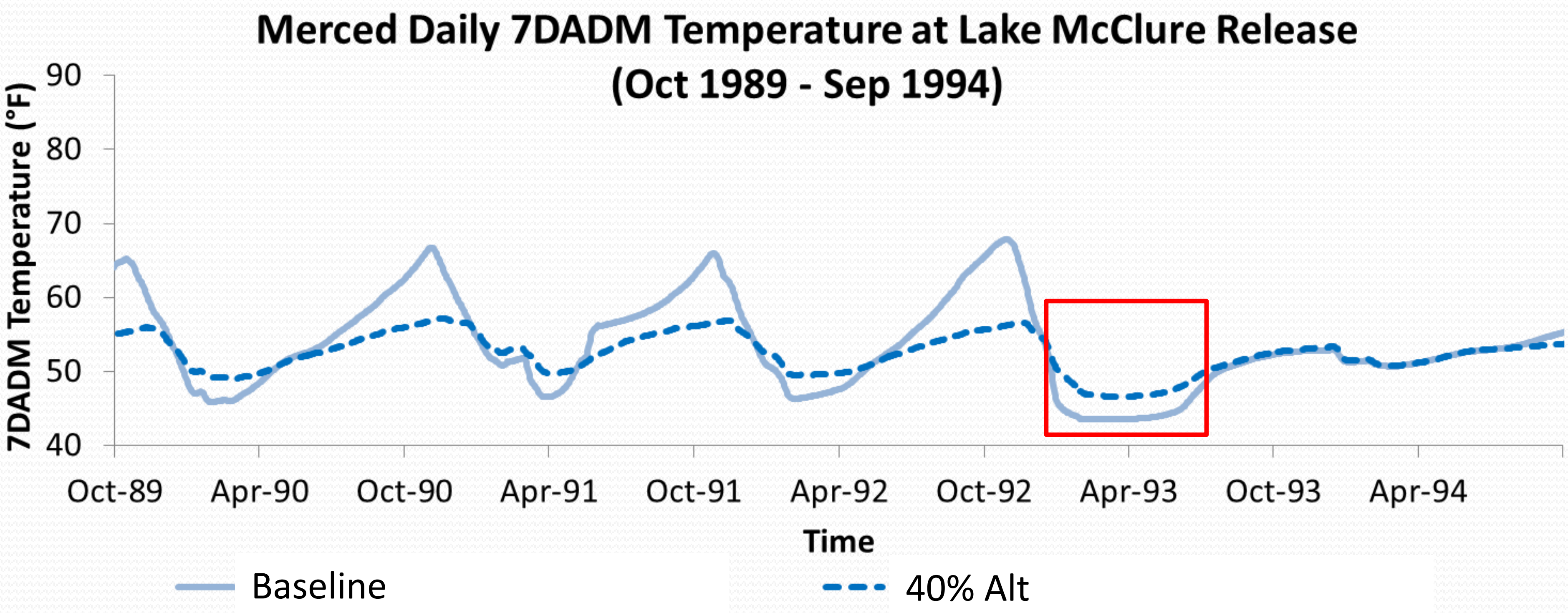

Lake McClure Storage (Oct 1989 - Sep 1994)
Storage (taf)
1400
1200
1000
800
600
400
200
0
Oct-89
Apr-90
Oct-90
Apr-91
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Apr-94
Time
Baseline
40% Alt
Flood Curve

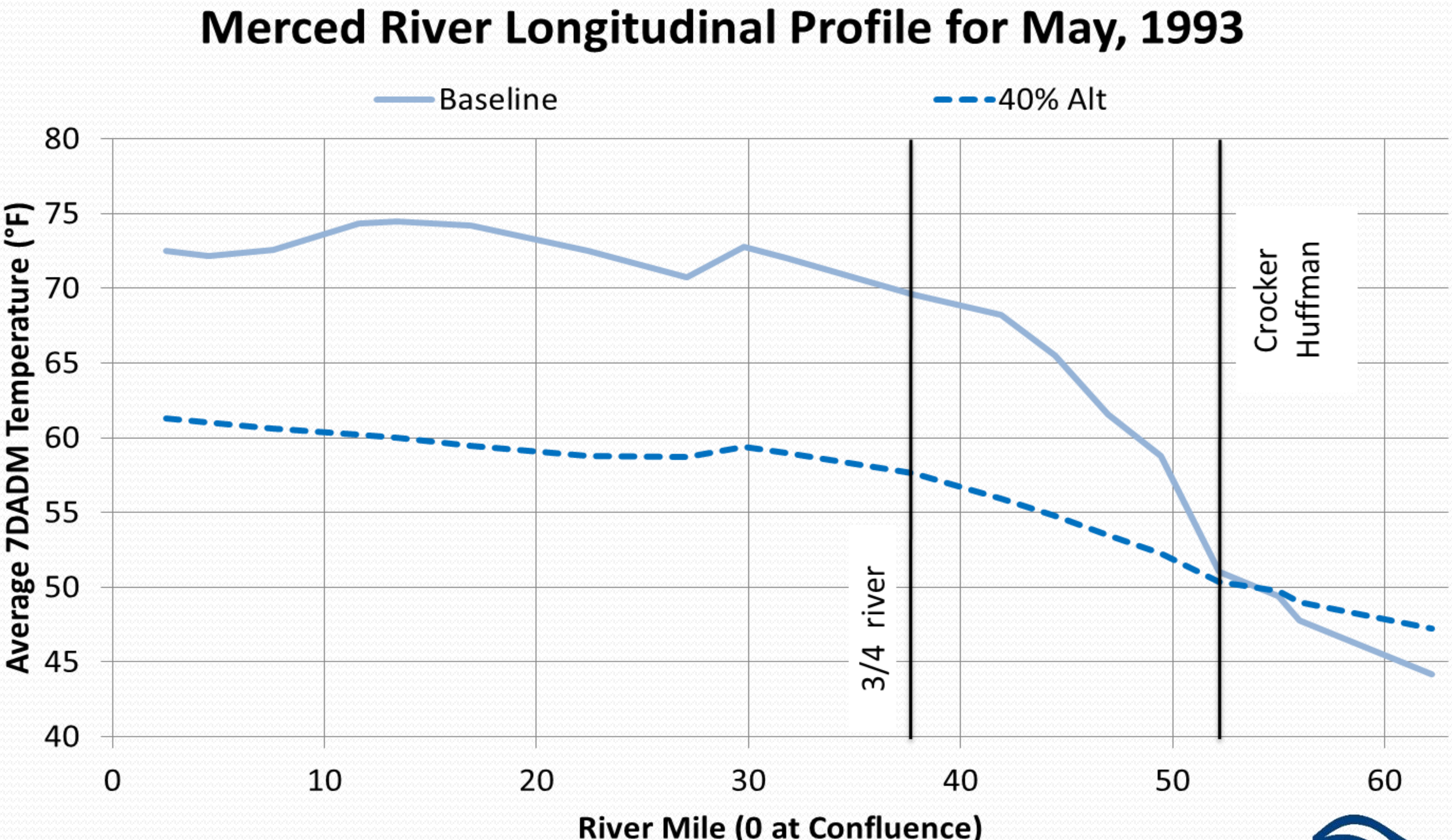

Merced Daily 7DADM Temperature at Lake McClure Release
(Oct 1989 - Sep 1994)
7DADM Temperature (°F)
90
80
70
60
50
40
Oct-89
Apr-90
Oct-90
Apr-91
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Apr-94
Time
Baseline
40% Alt

Merced River Longitudinal Profile for September, 1992




Lake McClure Storage (Oct 1989 - Sep 1994)
Storage (taf)
1400
1200
1000
800
600
400
200
0
Oct-89
Apr-90
Oct-90
Apr-91
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Apr-94
Time
Baseline
40% Alt
Flood Curve


Merced Daily 7DADM Temperature at Lake McClure Release
(Oct 1989 - Sep 1994)
7DADM Temperature (°F)
90
80
70
60
50
40
Oct-89
Apr-90
Oct-90
Apr-91
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Apr-94
Time
Baseline
40% Alt



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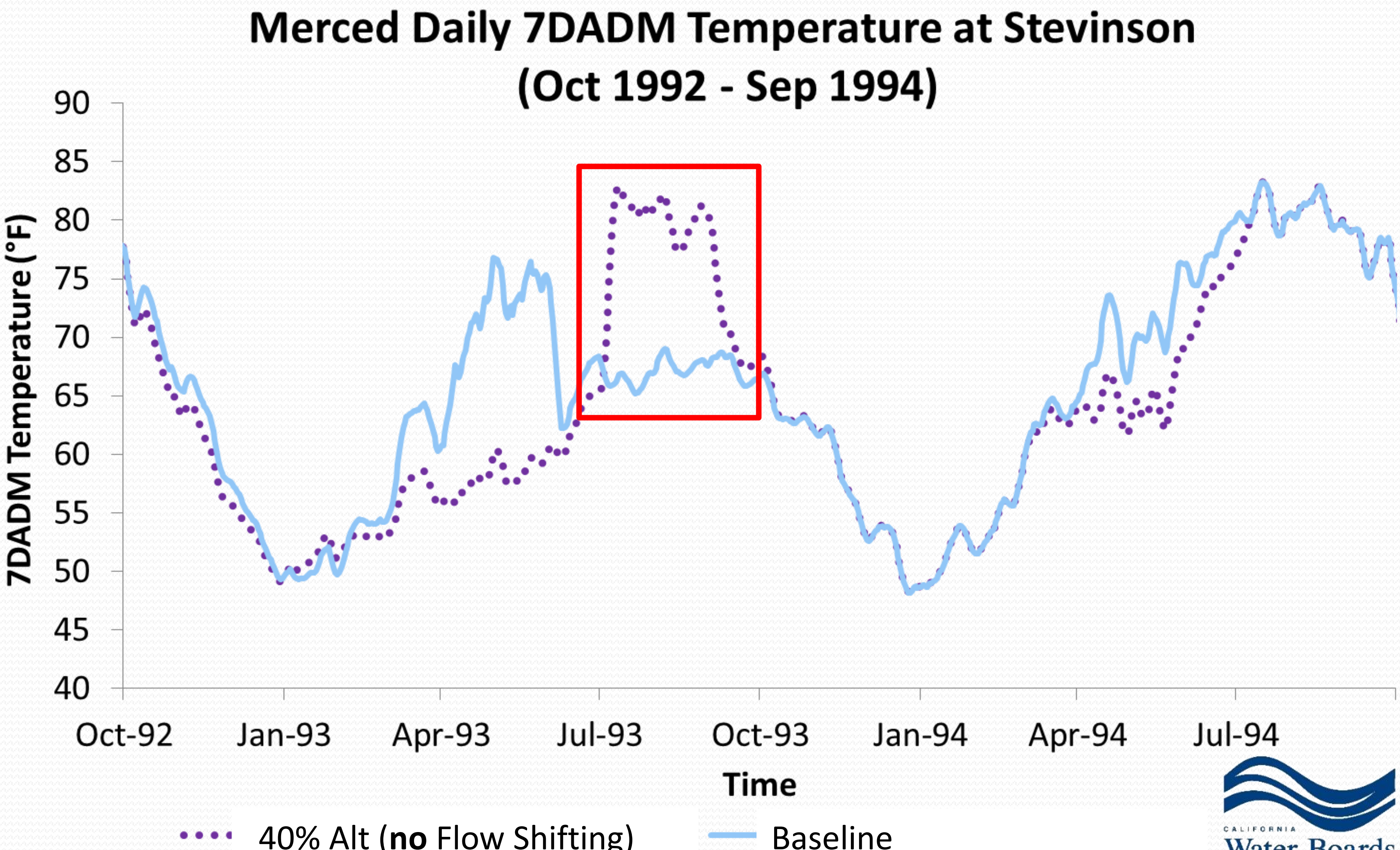
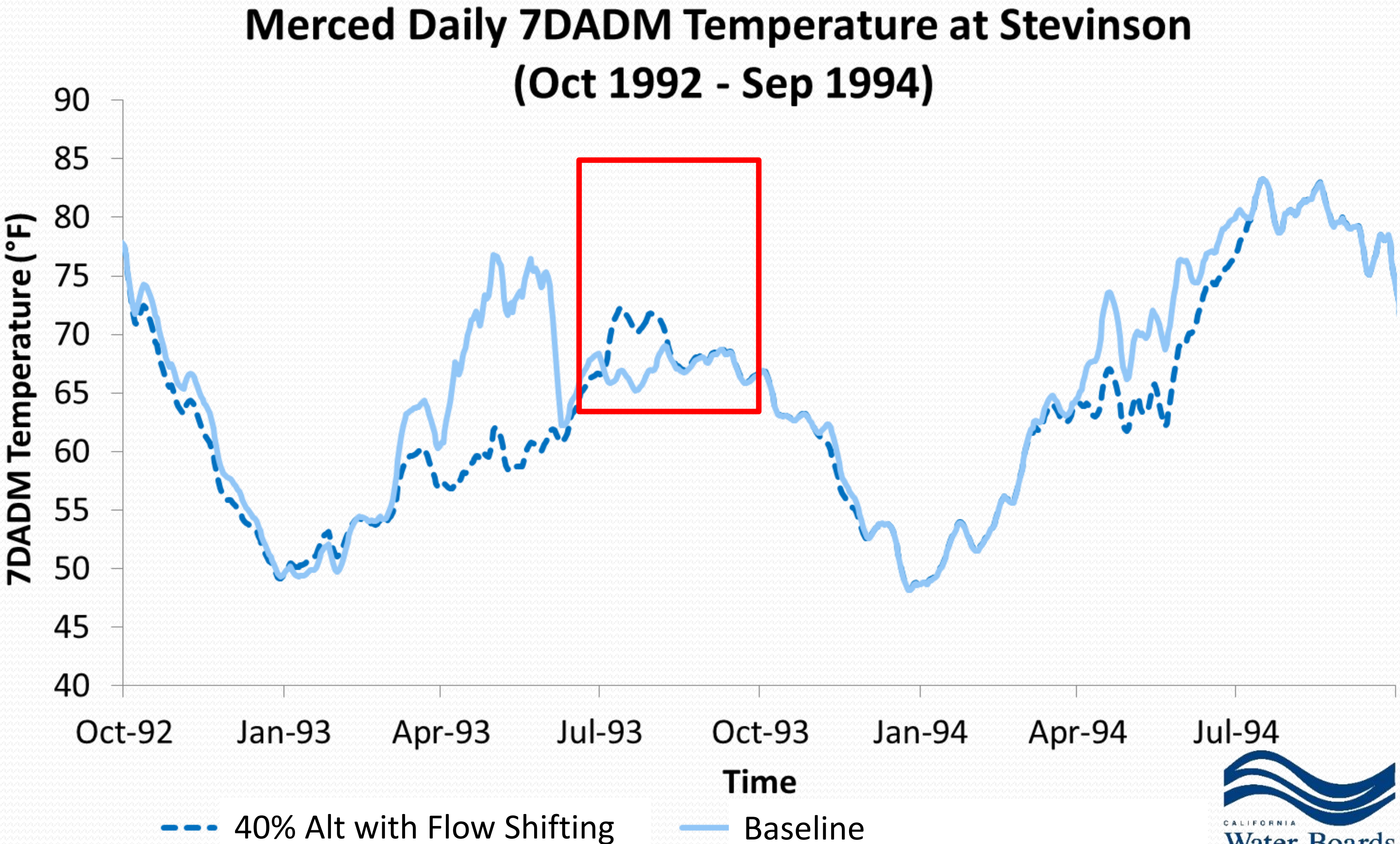
Effects of Flow Shifting

Effects of Flow Shifting



Effects of Flow Shifting



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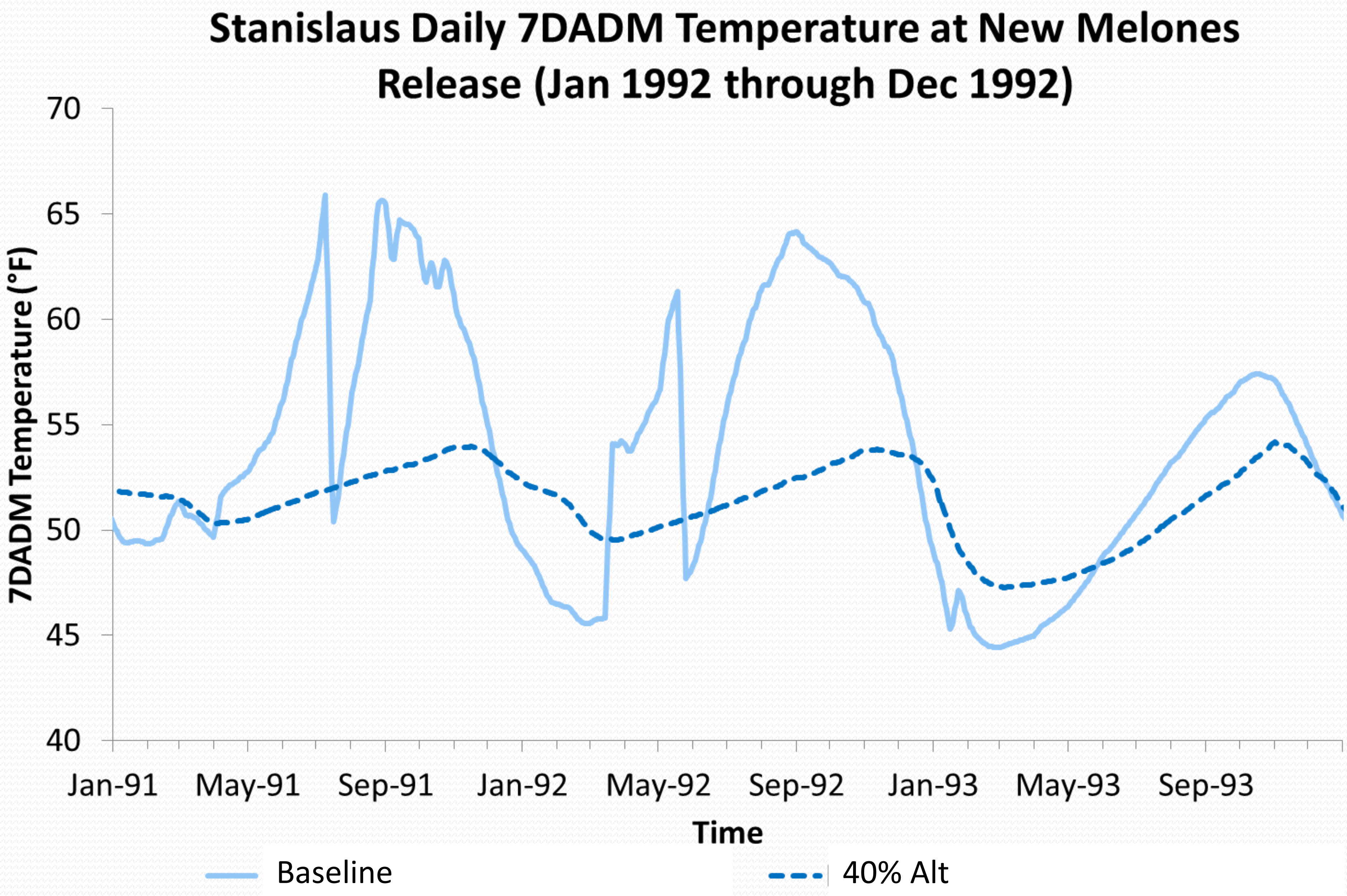
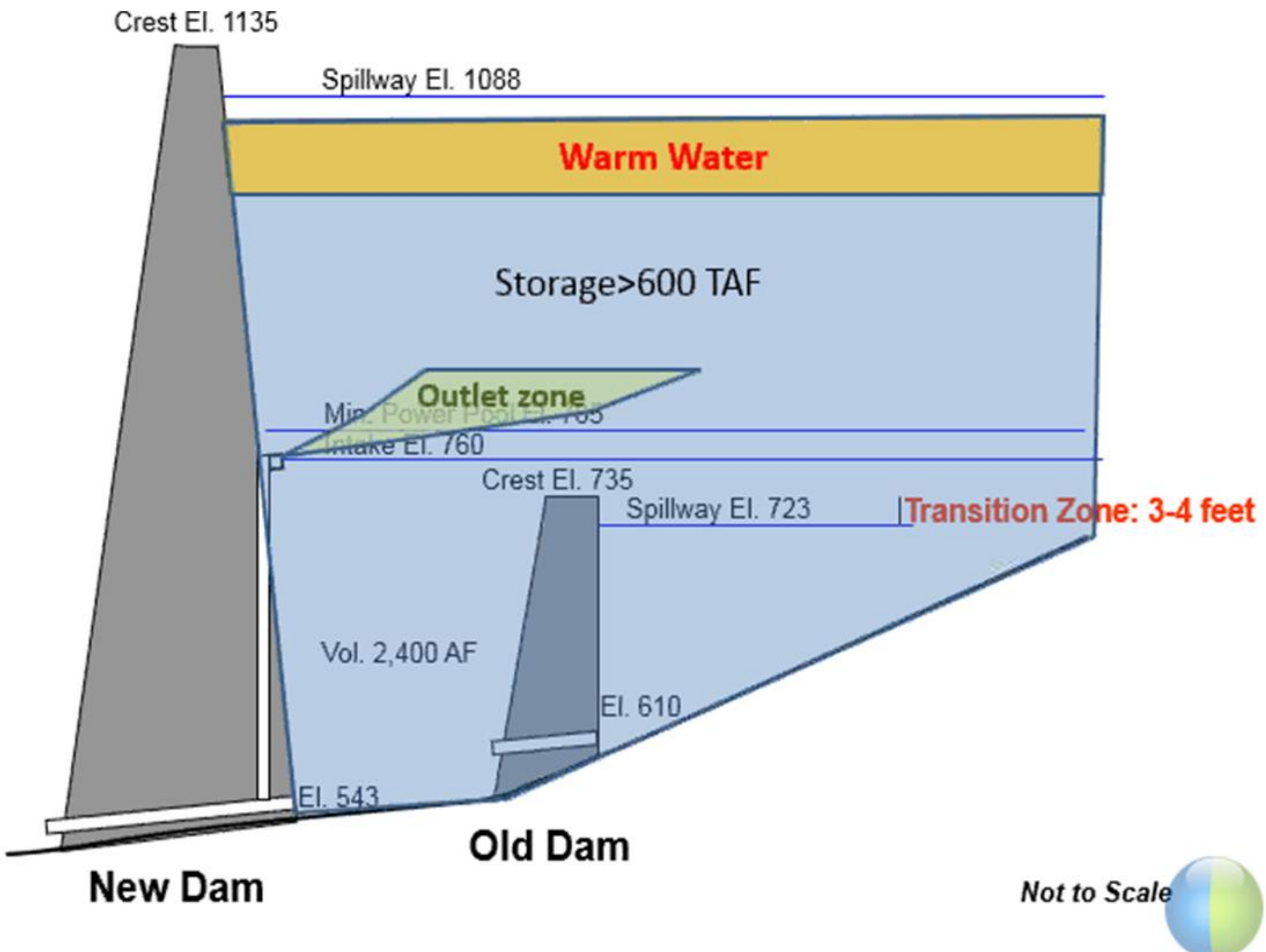
Other Noteable Temperature Dynamics


Stanislaus Daily 7DADM Temperature at New Melones Release (Jan 1992 through Dec 1992)
7DADM Temperature (°F)
70
65
60
55
50
45
40
Jan-91
May-91
Sep-91
Jan-92
May-92
Sep-92
Jan-93
May-93
Sep-93
Time
Baseline
40% Alt

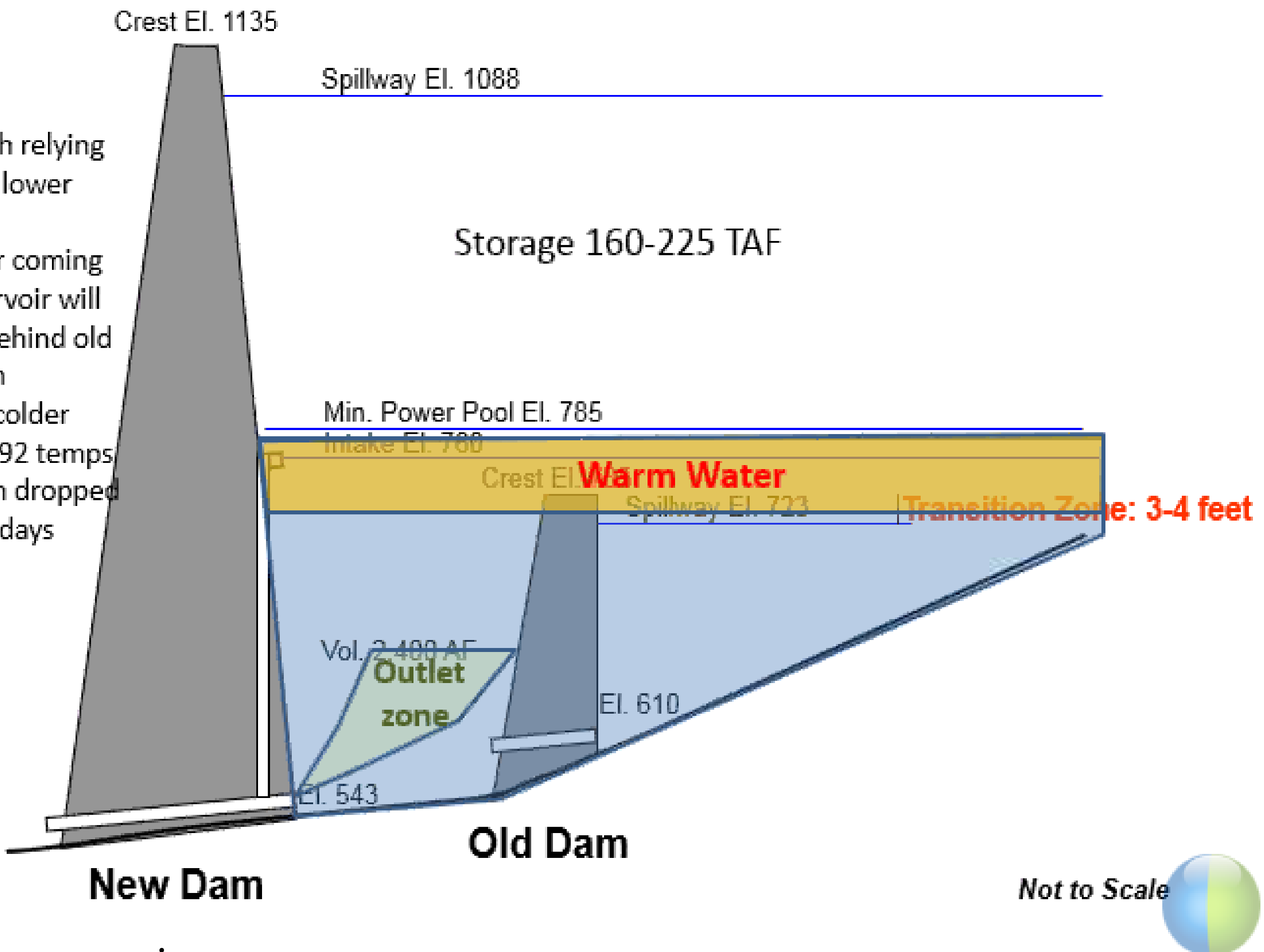
Temperature Effects between New Melones and Old Melones Dam



Source: USBR presentation

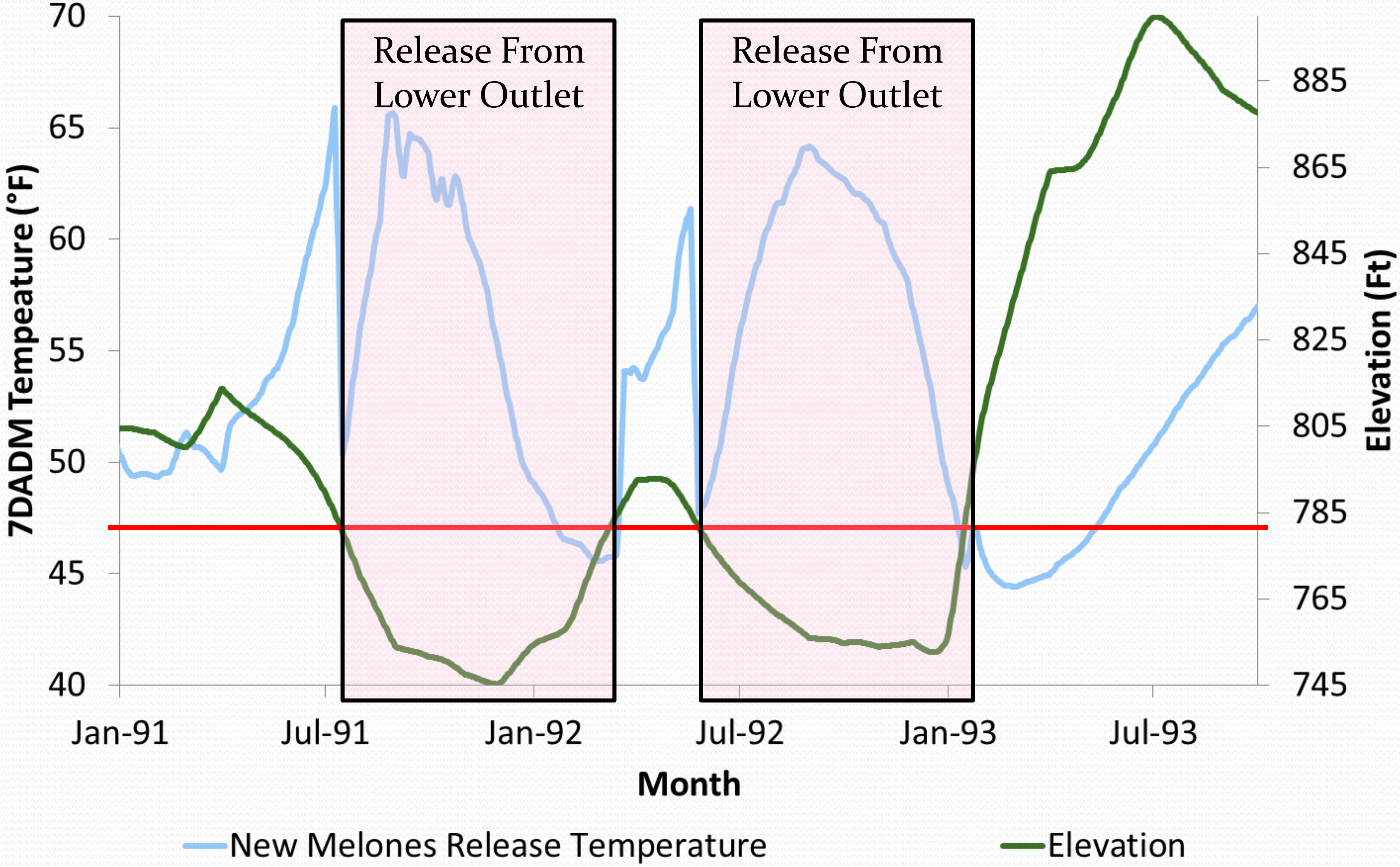
Temperature Effects between New Melones and Old Melones Dam

Notes:
- Concerns with relying solely on the lower level outlet
- All cold water coming into the reservoir will be trapped behind old Melones dam
- Significantly colder water – in 1992 temps below Tulloch dropped 10°F over 10 days



Source: USBR presentation

Daily Temperature of New Melones Releases vs. Reservoir Elevation Under Baseline Conditions (Jan 1991 through Sept 1993)

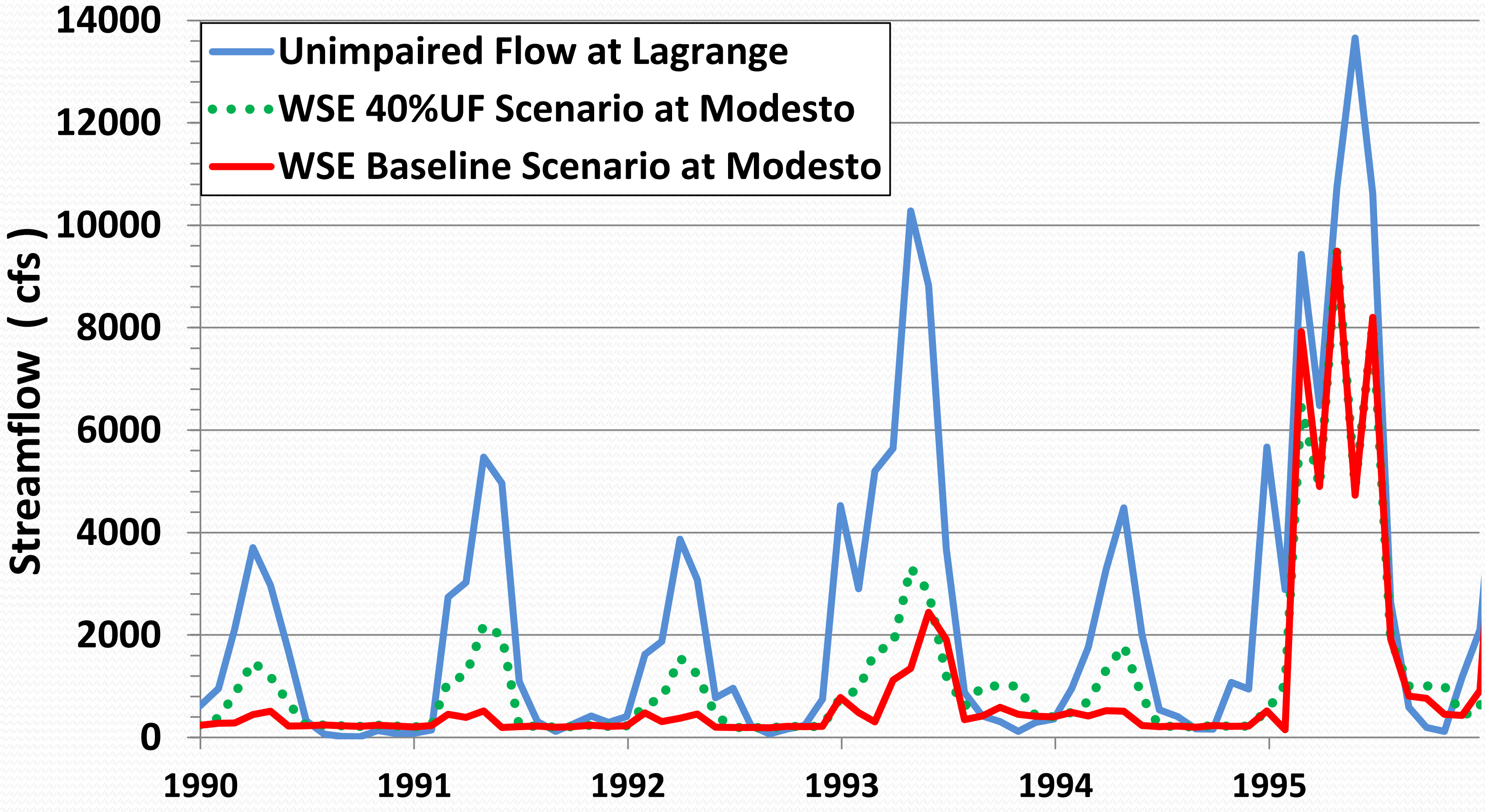


Temperature Evaluation Criteria

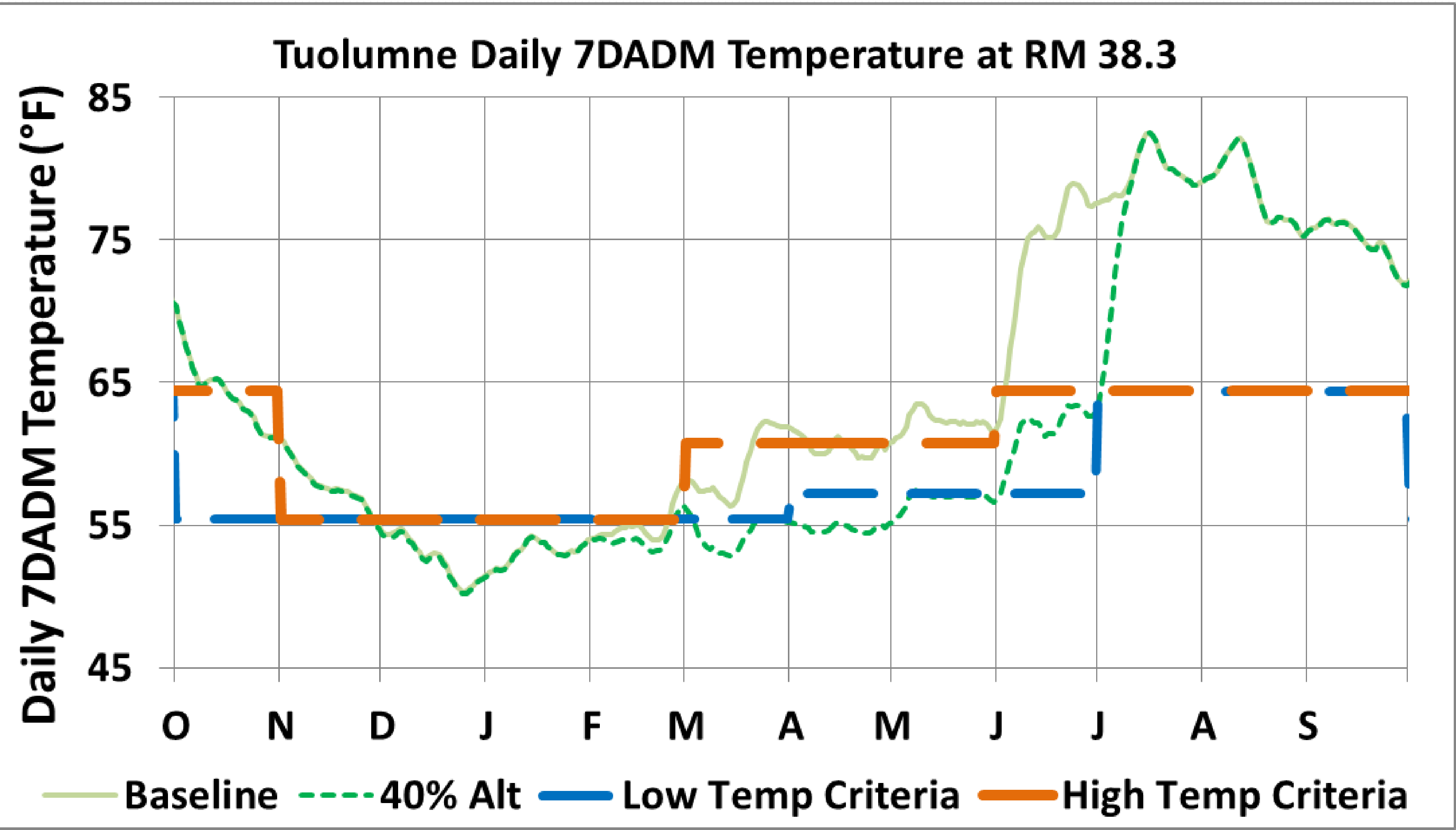
Evaluation Criteria – 7DADM (USEPA R10 2003)

- Spawning, Incubation, Emergence: **55.4 °F**
- Smoltification **57.2 °F**
- Core Juvenile Rearing: **60.8 °F**
- Summer Rearing: **64.4 °F**
- Adult Migration : **64.4 °F**

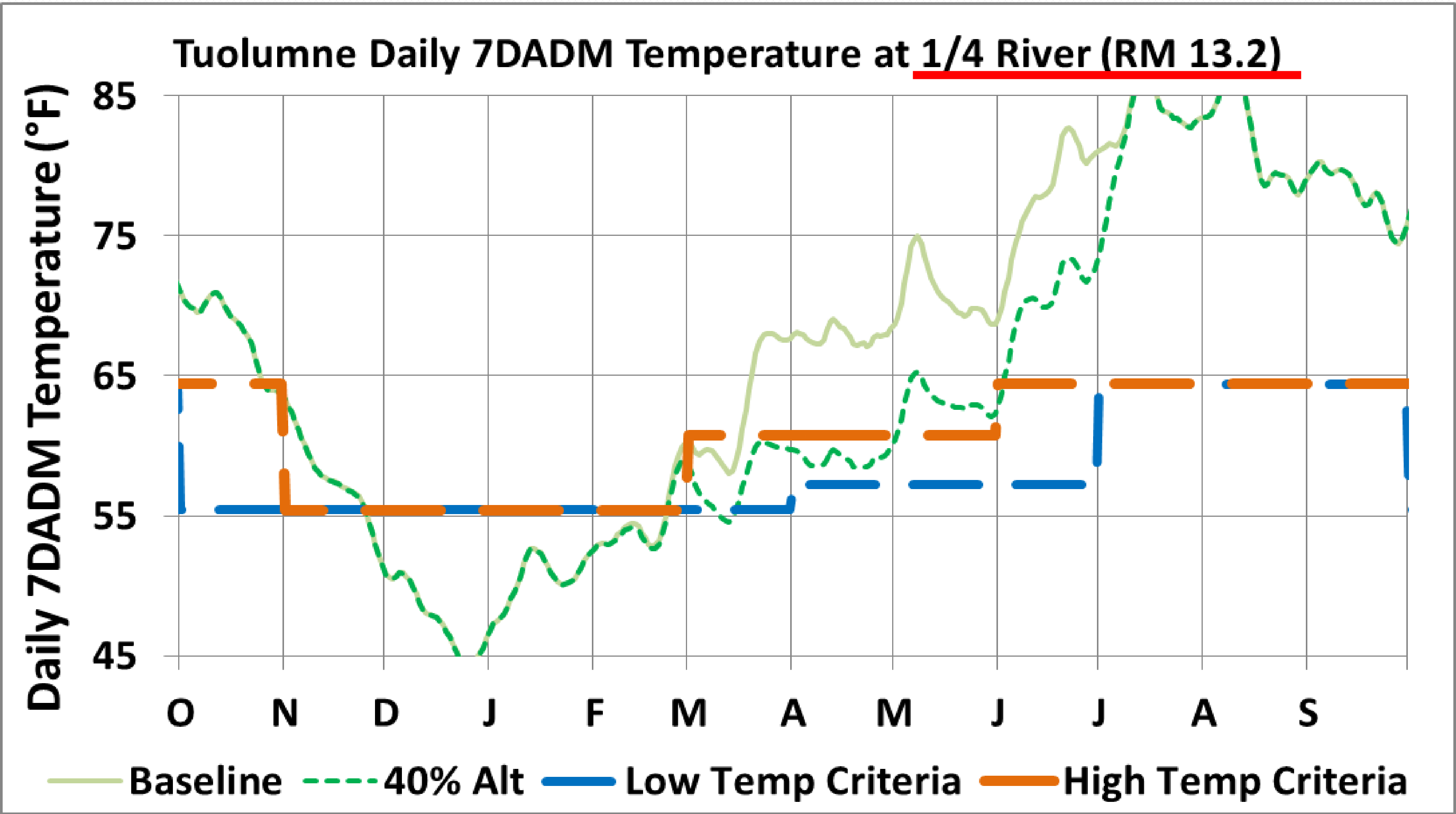
Tuolumne River (1990-1995)



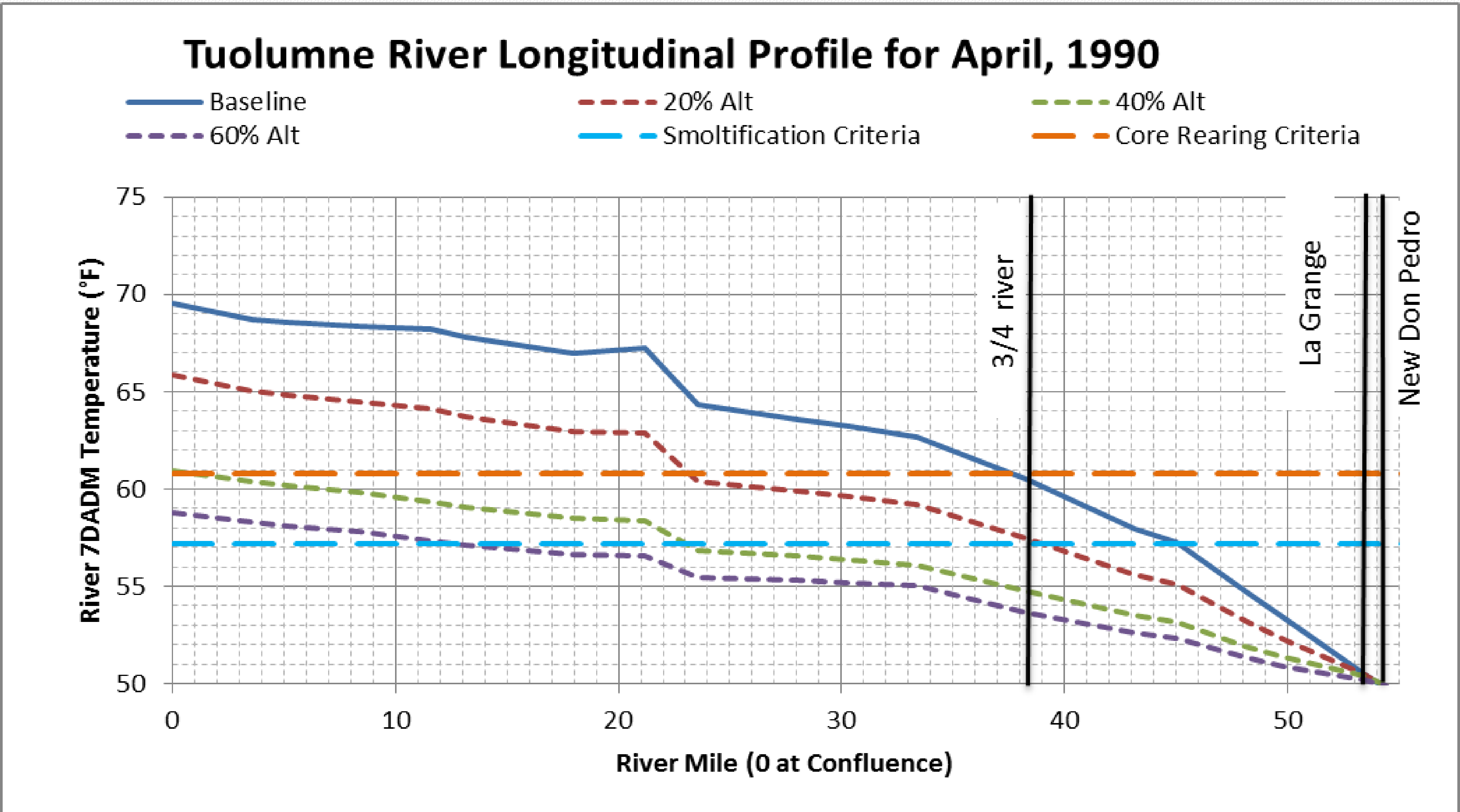
Tuolumne, Water Year 1990



Tuolumne, Water Year 1990 *(Downstream)*



Tuolumne, April 1990 (Monthly Average 7DADM)



Increase in Percent of Time Temperature Criteria Achieved – Merced River at River Mile 27

Life Stage	Month	USEPA Criteria (degrees F)	Base	Unimpaired Flow Percent				
				20	30	40	50	60
Reproduction	Feb	55.4	81%	-3%	-2%	-1%	2%	2%
Reproduction	Mar	55.4	29%	-1%	0%	3%	7%	13%
Core Rearing	Mar	60.8	85%	0%	3%	7%	9.8%	11%
Core Rearing	Apr	60.8	39%	-2%	17%	26%	38%	45%
Core Rearing	May	60.8	18%	6%	21%	26%	37%	43%
Smoltification	Apr	57.2	12%	0%	5%	6%	14%	19%
Smoltification	May	57.2	7%	0%	1%	1%	9%	15%
Smoltification	Jun	57.2	8%	-2%	-2%	-2%	-3%	-3%
Summer Rearing	Jun	64.4	26%	3%	8%	10%	16%	21%

Excerpted from SED Table 19-9

Further Information

- More information on these topics can be found in the following chapters and appendices of the SED:
  - Chapter F.1, *Hydrologic and Water Quality Modeling*
  - Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow between February 1 and June 30*
- These chapters, as well as information on how to obtain a copy of the temperature model and the SED temperature results, can be found at:

http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/2016_sed/index.shtml.

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